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MISSISSIPPIAN FORMATIONS OF SOUTHWESTERN NEW MEXICO

BY LOWELL R. LAUDON AND ARTHUR L. BOWSHER

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ABSTRACT

Mississippian rocks have been studied in detail over all of their area of exposure in southwestern New Mexico except in the Peloncillo and Little Hatchet mountain areas. Sections have been diagrammed and correlation charts prepared for all pertinent areas.

Rocks representing parts of all four standard Mississippi Valley series—Kinderhook, Osage, Meramec, and Chester—are present in New Mexico.

The Kinderhook is represented by the Caballero formation, a correlative of the Chouteau limestone (Chouteau = Compton of Moore, 1928), consisting of soft, nodular, fossiliferous, shaly limestone, resting unconformably on various parts of the Devonian and overlain by Osage beds.

The Osage series is represented by the Lake Valley, an early Osage formation, and the Kelly formation tentatively assigned to the Osage because of lithologic characteristics and stratigraphic position. The Lake Valley formation is divided into six members: Andrecito, Alamogordo, Nunn, Tierra Blanca, Arcente, and Dona Ana. Andrecito, Nunn, and Tierra Blanca are new names. The Andrecito consists of a variable series of soft, shaly limestone beds; the Alamogordo of hard, black, cherty, cliff-forming limestone; the Nunn of soft, blue-gray crinoidal marl beds; the Tierra Blanca of massive cherty criquina (closely packed, fragmental, crinoid skeletal parts in which even the separate columnals are broken (Tester, 1941, p. 6). This term is used throughout this paper for highly fragmental crinoidal limestone as opposed to normal crinoidal limestone in which the skeletal parts are relatively intact. The Arcente consists of thin-bedded, soft, relatively unfossiliferous siltstone; and the Dona Ana of massive, very cherty criquina. The Kelly formation consists of massive, gray, slightly crinoidal limestone of lighter color than the Lake Valley and is developed only in the western part of the area. Its relation to the underlying

Lake Valley formation has not been accurately determined. The Lake Valley and Kelly formations are absent from the Hueco and Franklin mountain areas.

The Meramec series is represented by two new formations, the Las Cruces and the Rancheria. Both were originally included in the Helms formation. The former formation consists of medium-bedded, dense, black, gray-weathering, chert-free, poorly fossiliferous limestone. It rests unconformably on Devonian beds and is overlain unconformably by the Rancheria formation. The Las Cruces formation is developed only in the Franklin Mountains and in the southern San Andres Range. The Rancheria formation consists of medium-bedded, very cherty, black, silty limestone. It rests with marked unconformity on both Devonian and Mississippian beds and transgressively overlaps northward in both Sacramento and San Andres mountain areas. In the Franklin and Hueco mountains, it is unconformably overlain by the Helms formation (restricted) of late Chester age. The *Leiorhynchus carboniferum* fauna occurs in the Rancheria formation making possible a direct correlation with the Moorefield formation of the Ozark region.

The Chester series is represented by the Helms formation (restricted) which consists of soft, green, sandy shales with nodular, fossiliferous limestone beds near the top and containing upper Chester fossils.

Mississippian rocks are unconformably overlain by Pennsylvanian strata. Evidence of marked relief on the erosion surface is common. In the San Andres Range, thick accumulations of reworked Mississippian cherts in basal Pennsylvanian beds offer strong evidence suggesting post-Mississippian orogenics.

The strange biohermal structures that characterize the Lake Valley formation in the Sacramento Mountains are locally, but less spectacularly, developed throughout the area of exposure of the Lake Valley formation.

INTRODUCTION

GENERAL STATEMENT

Mississippian rocks in New Mexico are of particular interest because they lie midway between the well-known deposits of the Mississippi Valley and the thick, but little-known, Mississippian deposits of our western States. Also, they lie in a direct line westward from the mountain ranges allied with the Appalachian Mountain system. Detailed information about trends of Paleozoic shore lines directly across trends of Rocky Mountain structure will do much to clarify misunderstood relations between so-called Appalachian and Cordilleran geosynclines.

Studies of the extensive faunas from the Mississippian formations of New Mexico permit accurate correlations with Mississippi Valley formations. Detailed stratigraphic work in New Mexico should be of great help in future studies of Mississippian rocks in the far western States.

Preliminary work on the Mississippian rocks of New Mexico was undertaken to ascertain stratigraphic occurrence of the prolific crinoid faunas that had long been known from the area. As the details of the stratigraphy were largely unknown, a rapid survey was made to determine the most pertinent facts concerning the Mississippian stratigraphy of this region. The complications of bioherm structure, the widely differing lithologic types, and greatly diversified faunas in the Mississippian rocks made necessary completion of detailed stratigraphic studies before the faunas collected from widely separated areas could be placed in their correct stratigraphic positions.

This paper is the result of detailed stratigraphic studies in all known exposed areas of Mississippian rocks in southwestern New Mexico (Fig. 1), except the Peloncillo and Little Hatchet mountains in the extreme southwest corner of the State. Mis-

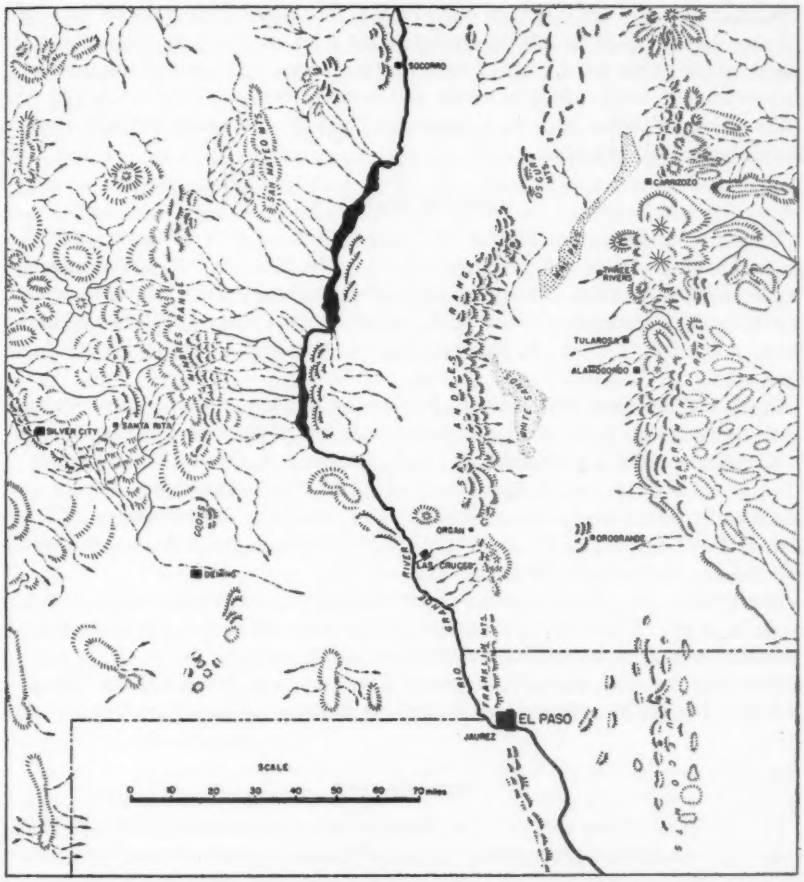

FIGURE 1.—*Map showing location of areas studied*

sissippian rocks have been studied and measured in the Sacramento (Laudon and Bowsher, 1941), Hueco, Franklin, Organ, San Andres, Cooks, Mimbres, and Lemitar mountains and in the Silver City—Santa Rita mining districts.

Investigation was necessary to verify recorded absence of Mississippian rocks from the Oscura, Sierra Caballos, Mud Springs, Robelero, and Florida mountains (Darton, 1928, p. 194, 319, 326, 334).

Sections were measured at intervals in each area where Mississippian rocks are

exposed. In over 80 per cent of the region exposures between measured sections were walked and studied in moderate detail.

The method used in diagramming sections in this paper is new; each diagram of four columns is one continuous section. The oldest beds are placed in the lower left-hand column of the diagram. The base of the second column should be superimposed on the top of the left-hand column, the third on top of the second, and the fourth on top of the third. This type of section is used because it allows maximum preservation of detail. System, series, and group names have been omitted to save space. One unfamiliar with the section must check the composite section for names above the rank of formation.

ACKNOWLEDGMENTS

Dr. A. N. Murray, Department of Geology, University of Tulsa, arranged for shipments of specimens and procurement of maps for field use. Field studies in the Organ Mountains were facilitated by A. O. Mineray of the Hilltop Mining Company, in the Franklin Mountains by Dr. L. A. Nelson, Texas College of Mines, and in the Silver City district by L. P. Entwistle of the American Smelting and Refining Company.

Frank V. Stevenson, International Petroleum Company, who has done extensive work on Devonian rocks of New Mexico, made his Mississippian fossils available; J. K. Johnston, R. L. Langenheim, Jr., H. B. Renfro, J. B. Carney, P. Aldridge, B. J. Chronic, W. V. Glass, and H. Wassal made available fossils that were not represented in our collections from the area; Dr. M. L. Thompson, Dr. C. C. Branson, Dr. L. A. Nelson, David Clark, and Mr. and Mrs. C. W. Wilson made available their collections of Mississippian fossils from New Mexico.

The officials of the Forest Service at Alamogordo and Silver City, of the National Park Service at White Sands National Monument, and of the Soil Conservation Service at Albuquerque have been helpful in furnishing maps.

Miss Mazzie Lane, Mr. O. T. Hayward, Mrs. Robyn Addis, Mrs. Enna Leonard, and Mrs. Bernita Mansfield, aided in drafting sections and in preparation of manuscript.

PREVIOUS WORK

Lower Carboniferous rocks of New Mexico were first described by White (1881, p. 671) in connection with the development of the silver mines at Lake Valley, New Mexico. Miller (1881, p. 306), later in the same year, described fossils of sub-Carboniferous age from the Lake Valley area. Cope (1882, p. 158) referred the rocks at Lake Valley to the Carboniferous system and is given credit for proposing the name Lake Valley. Silliman (1882, p. 424), apparently following Cope, also referred the rocks at Lake Valley to the Carboniferous system.

Springer (1884, p. 97) referred the Mississippian rocks at Lake Valley to the lower Burlington formation and listed a considerable portion of the fauna. Some of the fossil crinoids from the Lake Valley formation were described by Wachsmuth and Springer (1897) in their monograph on camerate crinoids.

Opening of the Kelly-Graphic Silver Mine in the Magdalena district led Herrick

1904, p. 310) to use the name Kelly for the Mississippian rocks in which the silver occurred. Gordon (1907, p. 801) measured and described the Kelly section and assumed that it was a northern extension of the Lake Valley limestone.

Formation names were assigned to Carboniferous rocks in Silver City, Santa Rita, and Fierro mining districts without regard to their stratigraphic relations to previously named formations in other mining districts of the State. Consequently, several synonymous formational names were proposed for the Mississippian rocks of this area.

Paige (1916, p. 5) introduced the name Fierro for limestone beds resting on the Devonian Percha shale and unconformably overlain by the Cretaceous Beartooth quartzite. He recognized that both Lower and Upper Carboniferous faunas were present but stated that pronounced lithologic differences were not found within the formation. The lower part of the Fierro was correctly correlated with the Lake Valley formation.

Schmitt (1933, p. 2) introduced the name Hanover for the crinoidal limestones forming the top portion of the Lake Valley formation in the Hanover mining district. From 80 to 150 feet of beds were involved in the section, and it appears that he included both Kelly and the top part of the Lake Valley formation in his Hanover.

Keyes (1906; 1908; 1939; 1940) added the names Berenda, Socorran, Grande, and Sierra to the literature. The U. S. Geological Survey does not recognize these terms (Wilmarth, 1938). Various names suggested by Keyes for Mississippian rocks of this area were discussed by Laudon and Bowsher (1941, p. 2109).

Gordon (1906; 1907) outlined the general stratigraphy of the Lake Valley limestone of New Mexico. Mississippian rocks in the Sacramento Mountains were first described by Darton (1917, p. 31). In descriptions of the Sacramento and San Andres ranges Darton (1922, p. 198) made the first attempt to correlate Mississippian formations throughout the area. In 1928, he published detailed descriptions of Mississippian rocks occurring in southwestern New Mexico with accompanying structure sections and generalized areal maps. The distribution of Mississippian rocks in both the Sacramento and the San Andres ranges was described by Darton essentially as the authors found it.

Darton (1917, p. 31) was the first to recognize Mississippian rocks in the Cooks Range. Five hundred feet were assigned to the Lake Valley formation and designated as Lower Carboniferous.

Early workers did not recognize Mississippian rocks in the Franklin and Hueco mountains (Richardson, 1909, p. 4). Mississippian rocks were included in the Hueco formation and placed in the Pennsylvanian system. The Helms formation was first described and considered Mississippian by Beede (1920, p. 7). His descriptions indicate that Devonian rocks were also included in the original definition of the Helms formation.

In a report on the stratigraphy of the Hueco Mountains, P. B. King and R. E. King (1929, p. 910) published columnar sections including Mississippian rocks. The Helms group as delineated by them includes rocks of Devonian and Mississippian age. Devonian chert and shales immediately beneath the Mississippian rocks in the Hueco Mountains were left in the Helms group, but the presence of Devonian fos-

sils in strata of similar lithologic characteristcis and stratigraphic position in the Franklin Mountains indicated to the authors that possibly rocks of several systems were included in the Helms group.

Rocks included in the original definition of the Helms formation in the Hueco Mountains were later divided into three members (P. B. King, 1934, p. 1537). The basal chert and overlying shaly limestones were referred to the Devonian. The middle slabby limestone beds were assigned to the upper Mississippian and the top shaly limestone beds to the Chester. King (1934, p. 1539) listed fossils collected from the middle member in the Franklin Mountains and identified by Girty as "*Leiorhynchus carboniferum*?" and "*Spirifer arkansanus*?". Girty also suggested (King, R. E., 1934, p. 1542) that this fauna strongly resembles that of the Moorefield formation of northwestern Arkansas.

Bowsher and Laudon (1942, p. 28) correlated the lower member of the Mississippian portion of the Helms group, as originally defined, with the Moorefield formation of Arkansas and suggested that the presence of *Graphiodactylus arkansanus* (erroneously called *G. fayettevillensis*) in the upper member of the Helms indicates possible correlation of this part of the section with the Fayetteville formation of northwestern Arkansas.

Most recent publication concerning Mississippian rocks in the Hueco mountain area is a detailed areal map by P. B. King, R. E. King, and J. B. Knight (1945, sheet 1). In a second part of the same report (P. B. King, and Knight, 1945, sheet 2) six sections showing Devonian and Mississippian rocks are diagrammed, correlated, and the sections described in part. The Helms is divided into two members. The lower member consists of brown, cherty limestones with occasional shales. The upper member contains two distinct lithologic units, a lower portion of brown flaggy, sandy limestone beds and an upper portion of shales and impure limestone. We believe that only the upper shaly portion of their upper member can be correlated with Chester beds. The break between the upper and lower members of the Helms formation as defined by King and Knight in the above report falls in the middle of the Rancheria formation as defined by us.

CLASSIFICATION OF MISSISSIPPIAN ROCKS

GENERAL STATEMENT

Many problems concerning classification of Mississippian rocks were left unsettled with the publication of the Mississippian correlation chart (Weller, 1948, p. 95). No attempt is made in this paper to deal with problems of classification unless the New Mexico area is directly affected. Detailed study of Mississippian rocks in western North America is uncovering much evidence that may help to solve many of the more difficult problems. Most recent writers recognize Kinderhook, Osage, Meramec, and Chester as valid series names. They are used in this paper.

Detailed studies of the faunas and lithology of the Chouteau limestone of Missouri, Caballero formation of New Mexico, Lodgepole limestone of Montana, and the lower portion of the Banff limestone of British Columbia have convinced us that they are all of early Kinderhook age.

Careful study of the prolific faunas of the New Providence formation of Kentucky, the Fern Glen formation of Missouri, the St. Joe formation of Arkansas and Missouri, and the lower portion of the Lake Valley formation of New Mexico has shown almost no species in common with the so-called Chouteau faunas. Common Osage species

Southwestern Missouri (Weller, 1948)	New Mexico (this report)
Pitkin Fayetteville	Helms
Moorefield	Rancheria
?	Las Cruces
Lower Burlington - - - - - - - - - - - - Fern Glen	Kelly Dona Ana Arcente Tierra Blanca Nunn Alamogordo Andrecito
Chouteau—"Compton"	Caballero

FIGURE 2.—*Correlation of Mississippian rocks of New Mexico with those of the southwestern part of Missouri*

appear in all of these formations so we have considered them as of early Osage age in this paper.

We do not subscribe to the classification used by Branson (1938 and 1948) in which he recognizes both Kinderhook and Osage formations within his Chouteau formation.

The Las Cruces and Rancheria formations lie with marked unconformity on Osage formations in New Mexico. Since they contain the *Leiorhynchus carboniferum* fauna we have considered them of Meramec age in this paper. We do not subscribe to the suggestion that they may be of Warsaw age (Weller, 1948, Pl. 2). We believe that the Warsaw formation should be classed with the Osage.

The Helms formation, restricted in this paper, is considered to be of Chester age.

ROCKS OF KINDERHOOK AGE

Caballero formation.—The name Caballero is retained essentially as defined (Laudon and Bowsher, 1941, p. 2116) for rocks of Kinderhook age. It varies from a feather edge to 60 feet thick and is absent in many areas. The Caballero formation consists of gray, nodular, in part mottled, shaly limestone with thin layers of gray calcareous shale curving between the nodular limestone beds. The basal part in many places contains a thin layer of fissile black shale. The Caballero unconformably overlies various Devonian formations and is overlain unconformably by the

Lake Valley formation. It contains a large fauna consisting mainly of small invertebrates but fossils do not make up a conspicuous part of the Caballero rocks. Both lithologic characteristics and fauna indicate that the Caballero formation is

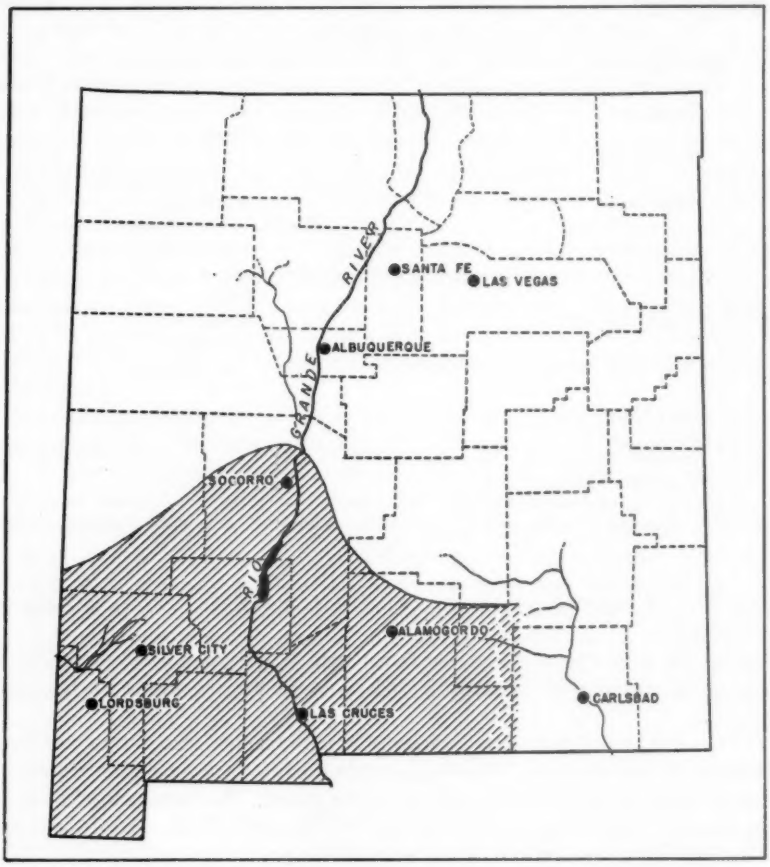

FIGURE 3.—*Original distribution of Mississippian rocks in New Mexico*

equivalent to the Chouteau formation of the Mississippi Valley area. It is best developed in the Sacramento Mountains, occurs in the central portion of the San Andres Mountains, and locally in the Lake Valley area (fig. 5). Elsewhere in New Mexico it is missing.

ROCKS OF OSAGE AGE

Lake Valley formation.—The Lake Valley formation was named by Cope (1882b, p. 214) shortly after the opening of the silver mines at Lake Valley. As originally

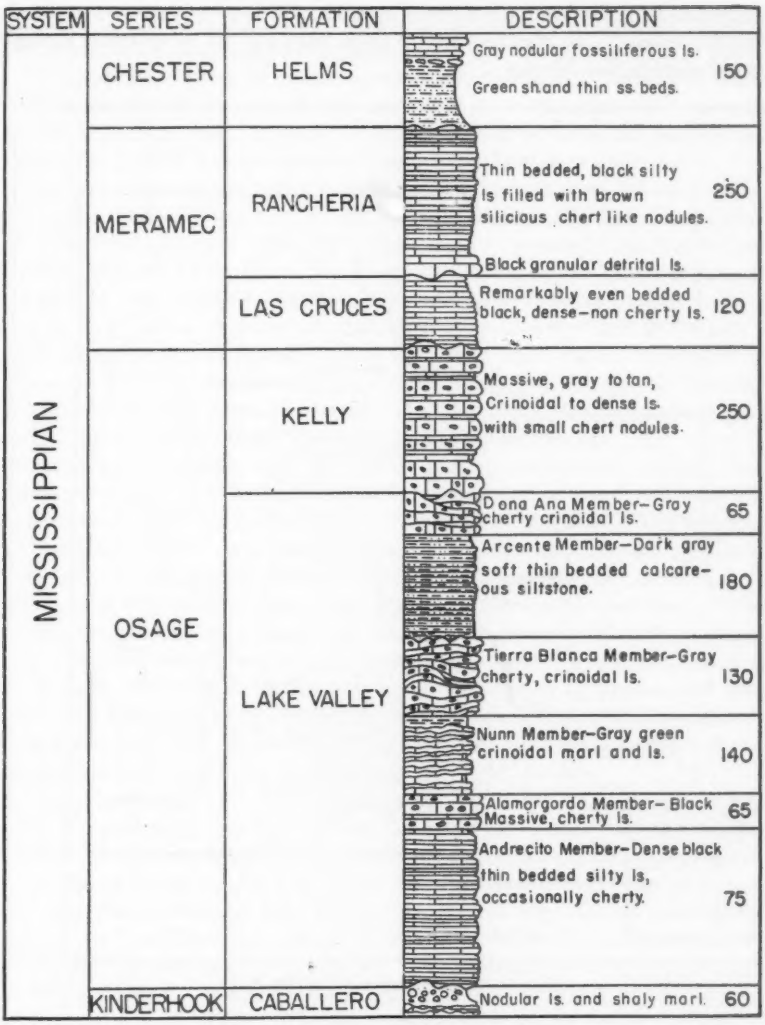

FIGURE 4.—*Composite Mississippian section*

defined, the formation included Caballero sediments at the base at Lake Valley. After detailed study the formation is divided into six members in this paper. In a previous work (Laudon and Bowsher, 1941, p. 2125) only three members were recognized. The single name Alamogordo was used for these beds because the normal succession in the basal portion is commonly replaced by bioherm structures. The Alamogordo member is now subdivided into four members, the name Alamogordo

being retained for the most conspicuous member, the second from the base in the normal succession. The members are lithologic units and are recognizable throughout southwestern New Mexico.

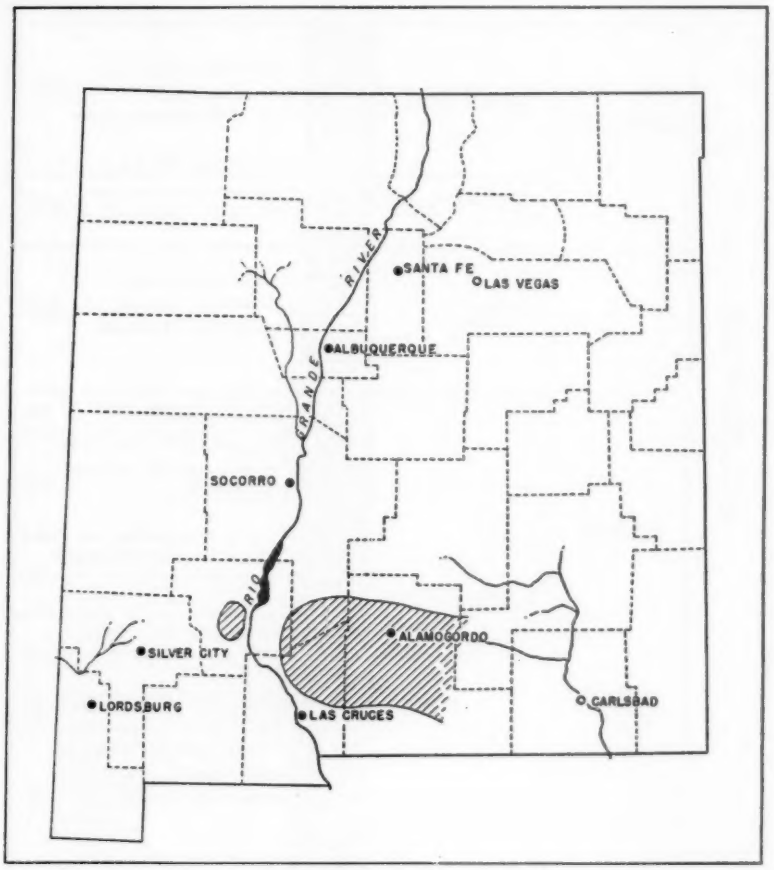

FIGURE 5.—*Distribution of Caballero rocks*

The Lake Valley formation (Figs. 6, 29) the most widespread Mississippian unit in southwestern New Mexico, rests unconformably on the Caballero formation or on Devonian sediments where the Caballero is missing. It is unconformably overlain by the Kelly formation in the western part of the area, by the Las Cruces and Rancheria formations in the southern part, and elsewhere by Pennsylvanian sediments.

ANDRECITO MEMBER: The name Andrecito is here proposed for the basal member of the Lake Valley formation and the type section is designated along the south wall of Andrecito Canyon (Fig. 21) in the San Andres Mountains in the NW¼, Sec. 8, T.

18 S., R. 4 E. At its type section, it consists of approximately 35 feet of thin-bedded, gray, fossiliferous limestone grading upward into thin-bedded, dark-gray, somewhat cherty limestone. The surfaces of limestone beds throughout the member are commonly covered with fenestelloid bryozoans. It rests unconformably on the soft, nodular Caballero formation and is easily differentiated from the massive, black, cherty, cliff-forming limestone beds of the overlying Alamogordo member.

The Andrecito member varies considerably in thickness and lithologic character throughout the area of exposure in New Mexico. In the Sacramento Mountains it is soft, gray, and silty, due mainly to the presence of reworked Caballero sediments. In the report on the Sacramento Mountains by Laudon and Bowsher (1941, p. 2126) this member was called the Taonurus siltstone. The member thickens northward from the type section in the San Andres Mountains to over 75 feet in the Rich Rim and thins again toward the north end of the range. In the Lake Valley and Silver City areas the member consists of very thin-bedded, non-cherty, very fossiliferous limestone beds. Maximum development is in the Cooks Mountains where approximately 270 feet of thin-bedded limestone belongs to this member.

ALAMOGORDO MEMBER: The Alamogordo member as originally defined (Laudon and Bowsher, 1941, p. 2125) included the beds designated in this report as Andrecito, Alamogordo, Nunn, and Tierra Blanca. The name Alamogordo is here restricted to the massive, black, very cherty, poorly fossiliferous, cliff-forming limestone beds above the thin-bedded Andrecito member and below the soft, blue-gray, crinoidal marls of the Nunn member (Fig. 12). The Alamogordo member (restricted) makes a conspicuous scarp along the front of the Sacramento Mountains and is the most widely distributed member of the Lake Valley formation. The thickness averages from 30 to 50 feet and is fairly constant. Variation in thickness occurs particularly where bioherms are developed. It forms the base from which the central biohermal structures rise. In many places it is part of the central biohermal structure. The member is thinnest in the Cooks Mountains.

NUNN MEMBER: The name Nunn is here proposed for the soft, blue-gray marls and nodular, crinoidal limestone beds that lie above the massive Alamogordo member and beneath the more massive, gray, cherty, criquina (Tester, 1941, p. 6) beds of the Tierra Blanca member. The type section is on Apache Hill at the type section of the Lake Valley formation near Lake Valley, New Mexico (Fig. 29). It is named for the Pryor Nunn Ranch[1] on Tierra Blanca Creek where excellent exposures and unusually prolific crinoid faunas have been collected. The famous Lake Valley crinoids occur in the Nunn member. Although crinoids occur in other members, the prolific faunas are invariably in the Nunn. The thickness varies from 100 feet in the Santa Rita area to 1 foot in the Sacramento Mountains. Rapid lateral variation in thickness is common in the Sacramento Mountains where biohermal structures occur.

TIERRA BLANCA MEMBER: The name Tierra Blanca is here proposed for the medium-bedded, gray to brown, criquina beds containing light-colored chert nodules

[1] Due to lack of geographic names in New Mexico and due also to lack of natural geographic features worthy of naming in areas chosen as type sections, the authors have been forced to depart widely from customary procedure. The type sections of the new units Nunn, Tierra Blanca, Las Cruces, and Rancheria are located at considerable distance from the geographic features for which they are named.

that cap the Mississippian section at Lake Valley and grade imperceptibly down into the soft blue-gray marls of the Nunn member. The type section is located on Apache Hill at the type section of the Lake Valley formation at Lake Valley, New Mexico.

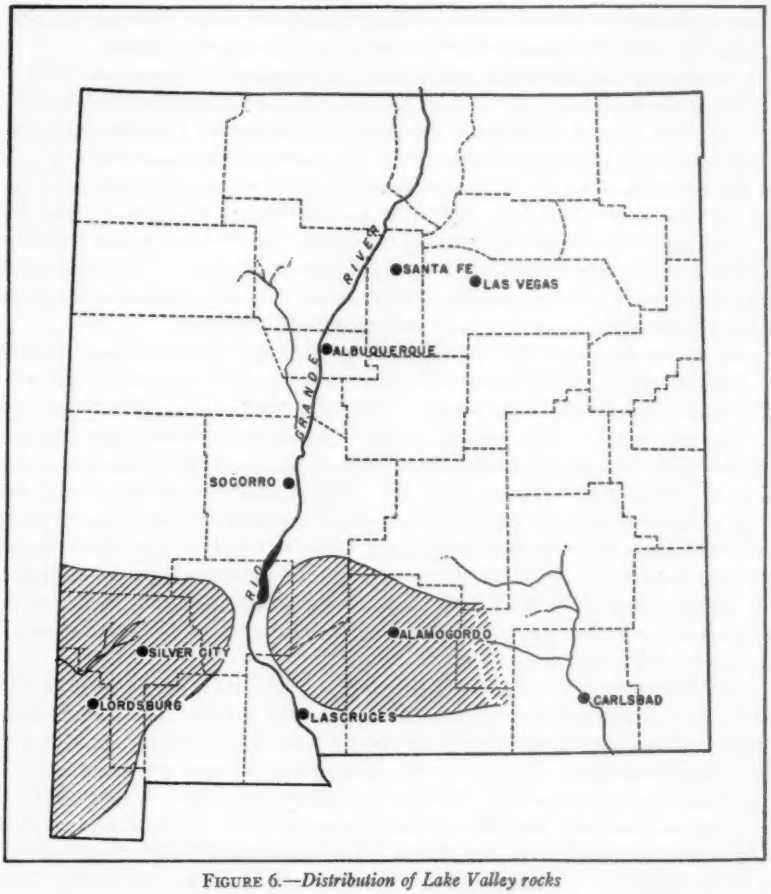

FIGURE 6.—*Distribution of Lake Valley rocks*

The member is named for Tierra Blanca Creek along which are excellent exposures in the vicinity of the Nunn Ranch. Most of the basal beds of the Tierra Blanca member are interbedded with blue-gray marl so that a definite line between Nunn and Tierra Blanca members is difficult to draw. The upper part is invariably gray to brown criquina with up to 50 per cent light-colored chert. The Tierra Blanca member is a cliff former and in most places makes a vertical scarp along the mountain front. Its thickness ranges from 125 feet in the Percha Creek area to 10 feet in parts of the Sacramento Mountains. Rapid lateral changes in thickness are common where biohermal structures are present.

ARCENTE MEMBER: The Arcente member retained as originally defined (Laudon and Bowsher, 1941, p. 2123), consists of soft, thin-bedded, gray, calcareous siltstone interbedded with thin laminations of soft, gray shale. It weathers to nodular, rubbly slopes and commonly makes a retreating portion of the mountain face. Typically the Arcente is poorly fossiliferous. It is present in the Sacramento Mountains and is locally present in the central part of the San Andres Mountains. In the Sacramento Mountains it reaches a maximum thickness of 230 feet, and in the San Andres Mountains is generally less than 25 feet thick. In the Mimbres Range, Cooks Mountains, and Silver City area the Arcente and Dona Ana members of the Lake Valley formation are missing.

DONA ANA MEMBER: The Dona Ana member retained as originally defined (Laudon and Bowsher, 1941, p. 2136), consists of medium-bedded to massive, gray to black, very cherty criquina (Fig. 12). Its maximum thickness is 175 feet in the vicinity of San Andreas Canyon in the Sacramento Mountains. Variation of thickness in the Sacramento Mountains is due largely to pre-Pennsylvanian erosion which has removed the Dona Ana in some areas. The upper surface of the Dona Ana is commonly dissected by deep solution channels. It is markedly fossiliferous in the Sacramento Mountains and contains a fauna of late lower Burlington age. The Dona Ana member, the least widespread member of the Lake Valley formation, occurs only in the Sacramento Mountains and in the central portion of the San Andres Mountains.

Kelly formation.—The Kelly formation (Figs. 7, 38) was named (Herrick, 1904, p. 310) for the Mississippian limestone in the Magdalena mining district, and especially for the limestone in the Kelly-Graphic mine. At Kelly it is approximately 125 feet of dense, tan to gray, sublithographic, somewhat massive limestone beds. Fossils are rare, although the upper beds are slightly crinoidal. The sequence is remarkably free from chert. In the Magdalena Mining district the Kelly formation rests directly on pre-Cambrian rocks and is overlain by Pennsylvanian shale.

The Kelly limestone is also exposed in the Lemitar Mountains where approximately 51 feet of somewhat cherty, gray to tan, slightly crinoidal limestone was measured in Corkscrew Canyon. Fossils are so rare in the Kelly limestone that the authors were unable to collect specimens for laboratory study. Very poorly preserved fragmental materials were studied *in situ* and inconclusively considered of late Osage age. The limestone in Corckscrew Canyon contains considerable amounts of gray and white chert, and is lithologically similar to beds referred herein to the Kelly formation in the Silver City area.

Mississippian limestone apparently belonging to the Kelly formation is exposed in the Sierra Ladrones (Darton, 1928, p. 17) but this area was not studied.

Somewhat massive, gray to tan, cherty, crinoidal limestone beds, tentatively referred to the Kelly formation are exposed in the Mimbres Range, the Cooks Range, and in the Silver City area. The chert nodules are smaller and less conspicuous than in the underlying Lake Valley formation but are similar to chert types found in Osage beds elsewhere. In some areas the contacts appear unconformable, but the exact relations to the Lake Valley formation are not certainly known. The maximum development of these rocks is on Bear Mountain west of Silver City, where slightly over 130 feet of cherty limestone was measured above the normal Lake Valley section.

Here again the fauna is so poorly developed that relative age is only tentatively considered late Osage. Additional collecting will be necessary to get fossils for age determination of this unit.

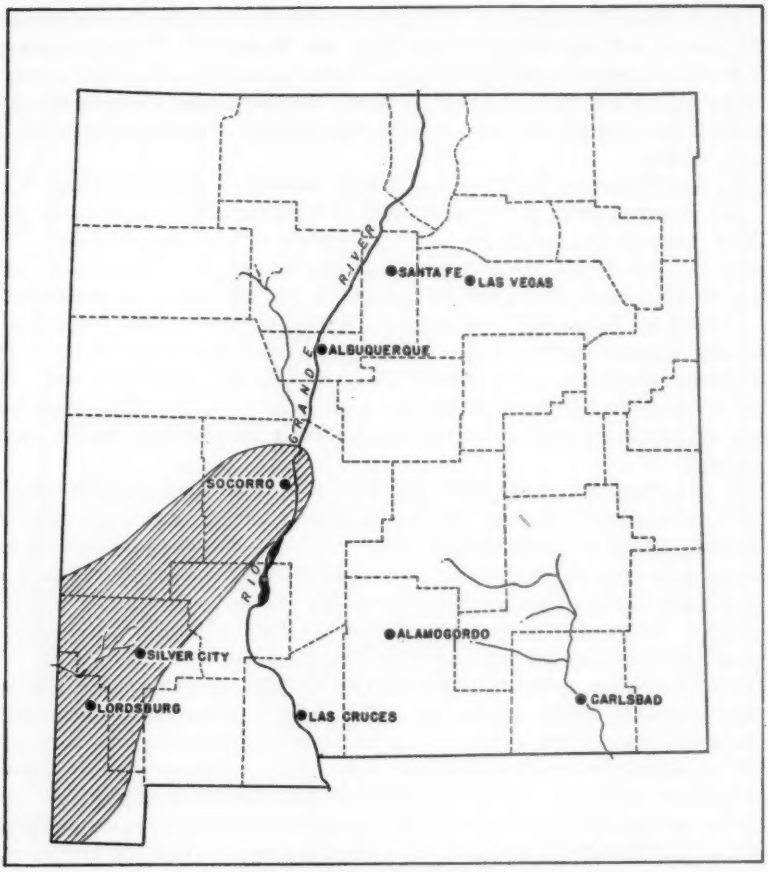

FIGURE 7.—*Distribution of Kelly rocks*

The Kelly formation does not occur in areas where rocks of Meramec age are exposed. In all areas of exposure the Kelly formation is overlain by rocks of post-Mississippian age. Lithologically it in no way resembles the Meramec rocks in New Mexico, but it is quite similar to the underlying Lake Valley formation and in the Mimbres Range can be separated from the Lake Valley only with difficulty.

ROCKS OF MERAMEC AGE

General discussion.—Confusion has arisen concerning the Meramec rocks in New Mexico because they were originally described as part of the Helms formation. The

original collections of Helms fossils apparently were made only from the upper, or Chester, part although the entire Helms section was assigned to the Chester series. P. B. King (1934, p. 1542) first recognized that the Helms formation was probably not a single unit when he submitted faunas collected from the lower part to Girty for identification. Girty (King, 1934, p. 1542) suggested that they were similar to faunas of the Moorefield formation of Arkansas, but at that time the Moorefield was not considered to be Meramec.

Faunas collected in the Hueco, Franklin, southern San Andres, and southern Sacramento Mountains unquestionably establish a Moorefield age for these strata. As the original Helms is now known to include rocks of both Meramec and Chester age, we propose to redefine the Helms formation by restricting the term to those strata containing Chester fossils, and proposing new formational names for the Meramec rocks.

Las Cruces formation.—The name Las Cruces is proposed for the hard, dense, black, sublithographic, even-bedded, gray-weathering, sparsely fossiliferous limestone beds that rest unconformably on the black "Percha" shale (Nelson, 1940—Canutillo fm.) and are unconformably overlain by the Rancheria formation in the Franklin Mountains (Figs. 8, 17). The type section is on the southwest side of the small south fork of the shallow canyon that leaves the west slope of the Franklin Mountains almost directly east of Vinton, Texas (SW¼, Sec. 67, S. Blk. 82, El Paso Co., Texas). The formation name is the same as that of the town of Las Cruces, New Mexico. The formation is distinguished by relatively thin, remarkably even beds, from 4 to 16 inches thick, averaging about 10 inches. It is free of chert at the type section. In this area no Caballero, Lake Valley, or Kelly beds have been found, and the Las Cruces rests directly on the "Percha" shale. The Las Cruces is unconformably overlain by the Rancheria formation with a conspicuous break.

The Las Cruces formation, which is little developed in New Mexico, is exposed mainly in the Franklin Mountains where it has a maximum thickness of approximately 60 feet in the type area. It overlaps northward and is exposed in the southern part of the San Andres Mountains, in Bear Canyon. The formation may also be present in the Hueco Mountains, but as yet it has not been recognized there or in the southern Sacramento Mountains.

The very meager fauna of the Las Cruces is not greatly unlike that of the overlying Rancheria formation and lithologically the Las Cruces is quite similar to some parts of the Rancheria. Differentiation of the two is difficult except on unusually good exposures. If it were not for the conspicuous unconformity between the Las Cruces and Rancheria formations and localized distribution of the former, it would seem unwise to propose a separate name for the Las Cruces formation.

Rancheria formation.—The name Rancheria is proposed for the sequence of cherty, black, bituminous, argillaceous limestone beds that rest unconformably on the Las Cruces formation and are unconformably overlain by the green shales of the Helms formation (restricted) in the Franklin Mountains of New Mexico (Figs. 8, 17). The type locality is designated on the southwest side of the small south fork of the shallow canyon that leaves the west slope of the Franklin Mountains, almost directly east of Vinton, Texas (SW¼, Sec. 67, S. Blk. 82, El Paso Co., Texas). The formation is named for Rancheria Peak in the Hueco Mountains where it is well exposed.

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The Rancheria formation exhibits a definite rock type throughout most of its vertical extent, although there are a few recognizable and stratigraphically usable zones. At the type section the basal beds are distinctive and sharply set off from

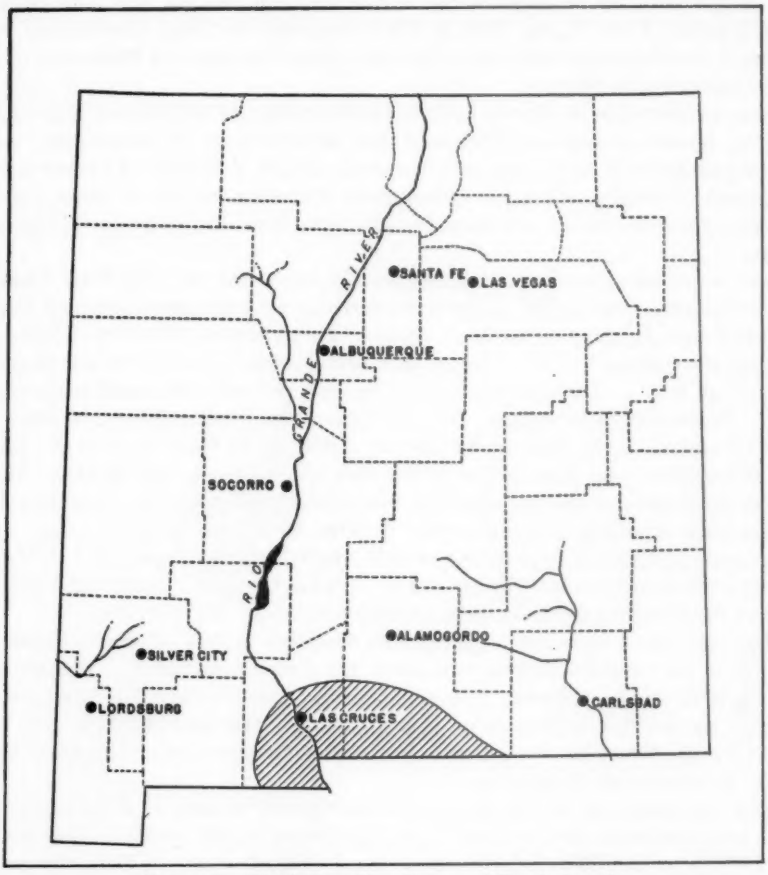

FIGURE 8.—*Distribution of Las Cruces and Rancheria rocks*

the rest of the formation. The basal few inches consist of black, detrital, sandy shale with small chert pebbles, phosphatic concretions, and a few fish teeth. Above the basal shale is a black, detrital quartz sandstone containing numerous plant fossils and considerable amounts of carbonaceous material. This is followed by 8 feet of soft, yellow to brown, sandy siltstone containing many specimens of *Leiorhynchus carboniferum*. Above the siltstone is a massive, black, bituminous, detrital limestone made up largely of minute fragments of crinoidal material. Nodules of black chert occur in the upper part of this limestone. This detrital limestone is apparently the material that caused King to suggest (1934, p. 1540) that a part of the

Lake Valley limestone might be present in the section. The remaining 235 feet of limestone at the type section is lithologically typical Rancheria medium-bedded, dense, black, silty limestone beds that weather brown. Except for one zone, about 45 feet thick, the 235 feet contain large amounts of peculiar, brown-weathering, porous chert, nodular or occurring in thinly laminated layers and streaks through the limestone. Because the limestone and chert both weather to a rich rusty brown, weathered slopes have the appearance of an old wood pile. All bedding planes between limestone beds are made of thin laminations of soft gray silty shale which thickens in places to 6 inches; at the south end of the Sacramento Mountains a few beds are several feet thick.

The Rancheria formation overlaps northward onto the eroded Lake Valley surface in the south end of the San Andres Mountains. In Bear Canyon the section approaches 200 feet in thickness. In the San Andres Mountains a 6-foot bed of jet-black chert occurs about 5 feet above the base. The top 60 feet is unusually thin-bedded and finely laminated. Fossils occur abundantly throughout the lower 100 feet of the Rancheria formation in Bear Canyon. In Ash Canyon, a few miles to the north, the section thins to approximately 15 feet, and it is missing in San Andres Canyon.

The Rancheria formation is exposed throughout the length of the Hueco Mountains. Measured sections have been described and diagrammed by King and Knight (1945, sheet 2). Throughout the Hueco Mountains the lower part of the Rancheria consists of cherty siltstone; the upper part is more thinly bedded, flaggy siltstone with considerably less chert.

The formation overlaps northward onto the eroded Lake Valley formation in the southern end of the Sacramento Mountains. In Nigger Ed Canyon the section is 275 feet thick. The same jet-black chert that occurs in the south end of the San Andres Mountains occurs at the base of this sequence. In Escondido Canyon the section has thinned to 112 feet with a corresponding thickening of the Lake Valley sediments beneath. The Rancheria is absent in the Dog Canyon area.

Because of the presence of the "*Leiorhynchus carboniferum* fauna" the Rancheria formation is correlated with the Moorefield formation of the Ozark area and is considered to be early Meramec.

ROCKS OF CHESTER AGE

Helms formation.—Beede (1920, p. 8) designated all rocks between the Silurian and Pennsylvanian systems in the Hueco Mountains as the Helms. This name is here restricted to the upper part of these strata. The Helms formation, thus restricted, consists of green shale, shaly sandstone, and impure limestone beds (Fig. 15), containing Chester fossils. In the type area, the Helms formation rests unconformably on the Rancheria formation and lies unconformably beneath Pennsylvanian rocks.

The Helms formation is exposed only in the Hueco and Franklin mountains (Fig. 9). In the latter it consists of about 98 feet of soft, green flaky shale with thin laminations of yellow sand, and contains gray, nodular, fossiliferous limestone beds in the upper 8 feet. The fauna is confined to the top part of the section in both Hueco and Franklin Mountains. Typical Chester species of *Archimedes*, *Pentremites*, *Composita*, and

Diaphragmus occur commonly. *Graphiodactylus arkansanus* occurs abundantly in the shales in the upper part of the Helms in the Franklin Mountains.

POST-MISSISSIPPIAN OROGENICS

Mississippian rocks are missing from the Mud Springs, Sierra Caballos, Robelero, and Florida Mountains. Distribution maps show that Caballero and Lake Valley

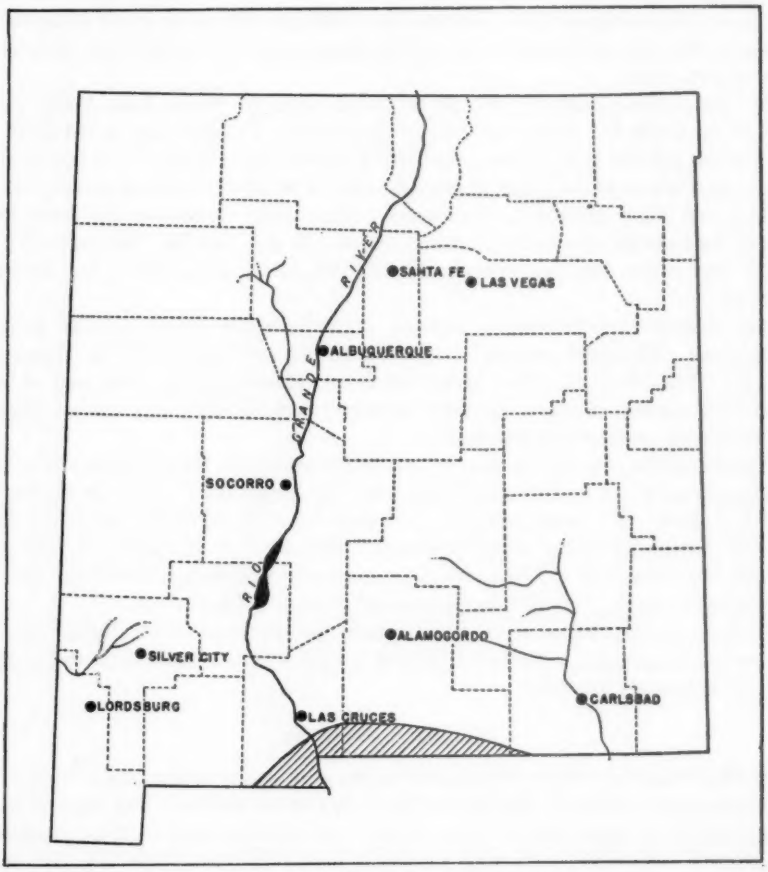

FIGURE 9.—*Distribution of Helms rocks*

sediments were almost certainly once present over most of this area. In the Mud Springs and Sierra Caballos Mountains, soft, marly shales, and nodular limestones of the Derry series (Pennsylvanian) (Thompson, 1942, p. 26) lie directly on the soft marls of the Sly Gap (Devonian) formation. No reworked Mississippian materials occur in the base of the Derry series. The contact is slightly undulating, with a marked oxidized zone, and an abrupt lithologic break.

In the Robelero Mountains igneous rocks have invaded along the contact between Pennsylvanian and underlying rocks, greatly obscuring relations. Limestones with Derry fossils occur at the base of the Pennsylvanian section. No Mississippian rocks were identified in the area.

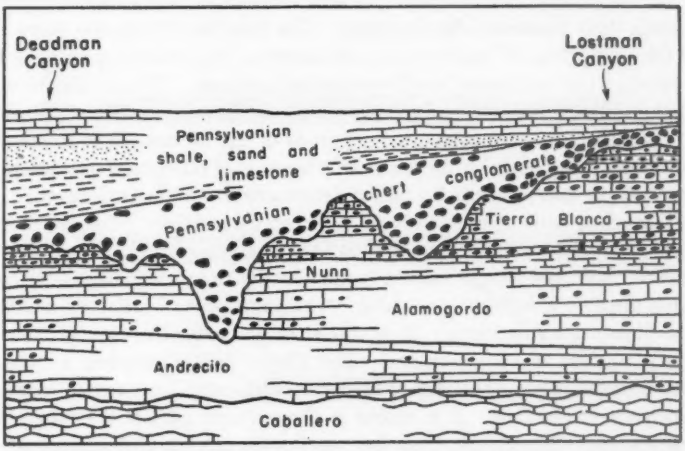

FIGURE 10.—*Diagram showing effects of post-Mississippian orogenesis as seen between Lostman and Deadman canyons, San Andres Mountains (Dona Ana Co.)*

In the Florida Mountains, Darton (1928, p. 329) reported Gym limestone of Permian age directly in contact with the Montoya limestone (Ordovician). We were unable to find any trace of Mississippian limestone beneath Pennsylvanian rocks on the southwest side of the mountains. The San Andres Mountains, 35 miles east of the Sierra Caballos Range, offer excellent evidence of post-Mississippian-pre-Pennsylvanian uplift of this area. Throughout the San Andres thick concentrations of rounded, reworked, Mississippian cherts are incorporated in the base of the Pennsylvanian section. Fossils from the entire Lake Valley sequence can be identified in these cherts. Concentrations of chert 75 feet thick are exposed in the area between Lostman and Deadman Canyons (Fig. 10). In one area on the north wall of Lostman Canyon a channel filled with reworked Mississippian chert is in contact with the Andrecito member of the Lake Valley formation. A pre-Pennsylvanian erosion channel which cuts through the whole of the Mississippian and 45 feet into the Devonian strata was examined on the north wall of Rhodes Canyon, San Andres Mountains, just north of the highway.

The area uplifted at the end of Mississippian time, along 107°10′W. Long., apparently had a north trend because almost a full section of Lake Valley limestone occurs all along the east side of the Mimbres Range only a short distance to the west and throughout the San Andres Mountains to the east.

The low arch of uplifted area could have connected to the northeast with the Pedernal land mass (Thompson, 1942, pl. I) but as Mississippian rocks are absent from the Oscura Mountains and ranges to the north of this area, relations to the Pedneral land mass cannot be established.

STRATIGRAPHIC DISCUSSION OF LOCAL AREAS

SACRAMENTO MOUNTAINS

Summary.—Mississippian rocks plunge beneath the valley floor in the northern part of the Sacramento Mountains in the area in which Kinderhook and Osage sediments reach their maximum development. The Caballero formation thins rapidly toward the south (Fig. 11) and varies in thickness in the northern part of the range due to relief on pre- and post-Caballero erosional surfaces. The Andrecito member of the Lake Valley formation is silty throughout the Sacramento Mountains because of the reworked Caballero sediments in the base of the former. The member thins toward the south end of the range apparently because of transgressive overlap. The silty limestone of the Andrecito is easily differentiated from the hard, massive, scarp-forming limestone beds of the overlying Alamogordo member. The latter remains fairly constant throughout the Sacramento Mountains, except where complicated by bioherm structure, and toward the south end where it thins by transgressive overlap. The Nunn member is extremely variable in the Sacramento Mountains mainly as a result of biohermal structures. It is absent in the southern part of the range apparently because of nondeposition. The Tierra Blanca member is variable in thickness because of complications of biohermal structure, pre-Arcente erosion, and pre-Pennsylvanian erosion. It is absent in the southern part of the range because of nondeposition. The Arcente member reaches its maximum development in the northern part of the range and thins rapidly toward the south mainly because of pre-Rancheria erosion. The Dona Ana member is excellently developed in the northern portion of the region, thins rapidly toward the south mainly because of pre-Rancheria erosion, and is absent in the southern part of the range. The Rancheria formation thins by transgressive overlap from the south toward the north, and is missing in the northern part of the range (Fig. 12). Pennsylvanian sediments rest on the underlying Mississippian surface with marked unconformity. Evidence of relief over very short distances on the underlying Mississippian surface can be demonstrated. In the northern part of the range reworked chert conglomerates occur in deep channel fills that have been cut into the Mississippian surface.

General description.—The Tularosa Basin is a graben (?) lying between the west-facing scarp of the Sacramento Mountains and the east-facing scarp of the San Andres Mountains. The Sacramento Mountains rise highest above the valley floor in the area immediately south of Alamogordo, New Mexico. In general the rocks of the Sacramento Mountains dip east toward the plains of eastern New Mexico.

Mississippian formations crop out prominently all along the west face of the Sacramento Mountains from the vicinity of Indian Wells, 3 miles northeast of Alamogordo, New Mexico, south to the vicinity of Grapevine Canyon. Mississippian rocks plunge beneath the gravels of the valley floor midway between Nigger Ed Canyon and Grapevine Canyon. In the northern part of the range the Lake Valley formation forms prominent escarpments plainly visible from well out in the Tularosa Basin.

Mississippian rocks lie unconformably on the Devonian strata in the Sacramento Mountains. The contact is not marked by clastic rocks, and the relief on the surface is not great. The basal Mississippian rocks rest on the Sly Gap formation with the

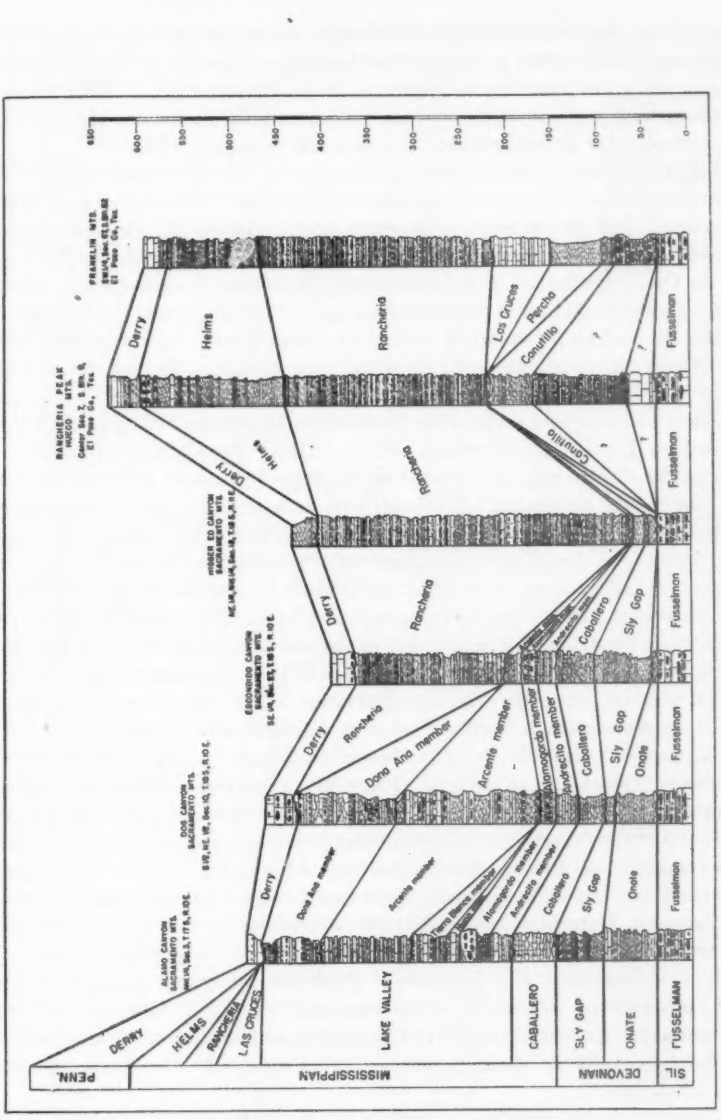

FIGURE 11.—*Correlation of sections—Sacramento, Hueco, and Franklin mountains*

(Alamo Canyon and Dog Canyon sections from Laudon and Bowsher, 1941.)

exception of one local exposure in Marble Canyon where they rest on the Contadero formation (Stevenson, 1945, p. 235). Pre-Mississippian erosion in the Sacramento Mountains has at no place cut as deeply as the Onate formation. The Devonian rocks consist largely of soft shales and the maximum relief on the pre-Mississippian erosion surface in the Sacramento Mountains is not more than 35 feet.

Mississippian rocks are unconformably overlain by Pennsylvanian rocks in the Sacramento Mountains. Pre-Pennsylvanian relief on the Mississippian surface was well developed, and the contact is everywhere sharp. In the Marble Canyon area, the Mississippian surface is channeled, resulting in over 200 feet of relief within a few miles. In the northern part of the Sacramento Mountains reworked chert concentrates occur in the basal beds of the Pennsylvanian. In other parts of the Sacramento Mountains the contact is commonly marked by coarse quartz conglomerate or sandstone. Where higher Mississippian erosional hills were left, Pennsylvanian limestones lie directly on the Mississippian rocks (Fig. 10).

The oldest Mississippian rocks in the Sacramento Mountains belong to the Cabellero formation (Laudon and Bowsher, 1941, p. 2116). The Caballero formation in the area can be divided into three rather poorly defined members, although all three are not everywhere developed. The basal part ordinarily consists of thin-bedded, black, fissile, pyritic shale whose maximum thickness is less than 4 feet. The basal material just above the contact is oxidized red. It usually contains fish teeth and phosphatic (?) concretions. The black basal shale is overlain by gray, markedly nodular, slightly mottled, silty limestone beds which form the more resistant portion of the Caballero formation. The nodular limestone beds average about 3 inches thick and are interbedded with thin curving partings of soft, calcareous shale. As this is the most resistant part of the Caballero formation, a low, rounded scarp is generally formed along the mountain front. This more resistant part is rarely over 15 feet thick. The upper beds of the Cabellero formation differ only in that the shale partings gradually thicken toward the top. There is no sharp line of separation between the more resistant nodular limestone beds near the base and the softer upper beds. In some parts of the mountains the upper beds consist mainly of soft calcareous shale with rows of discontinuous nodular limestone beds in the shales. Layers of calcareous shale as much as 3 feet thick without nodular limestones are common near the top.

The Caballero formation looks relatively unfossiliferous but careful collecting yields a remarkably diversified assemblage of small fossils. The presence of abundant *Dictyoclostus calhounensis*, *D. chouteauensis*, *Productina sampsoni*, *Avonia boonensis*, *Spirifer louisianensis*, *Reticularia cooperensis*, and *Phillipsia sampsoni* indicates Kinderhook age. As both litholigic characteristics and fauna are remarkably similar to the Chouteau limestone of the Mississippi Valley area, the Caballero is correlated with the Chouteau.

The Caballero is unconformably overlain by the Lake Valley formation in the Sacramento Mountains. The contact is generally difficult to find because the soft upper Caballero sediments were reworked by the incoming Lake Valley sea and the basal Lake Valley beds are ordinarily similar to the Caballero in color and lithologic characteristics. The Caballero formation is thickest in the vicinity of Mule and San Andres canyons and thins to slightly more than 12 feet at its southernmost

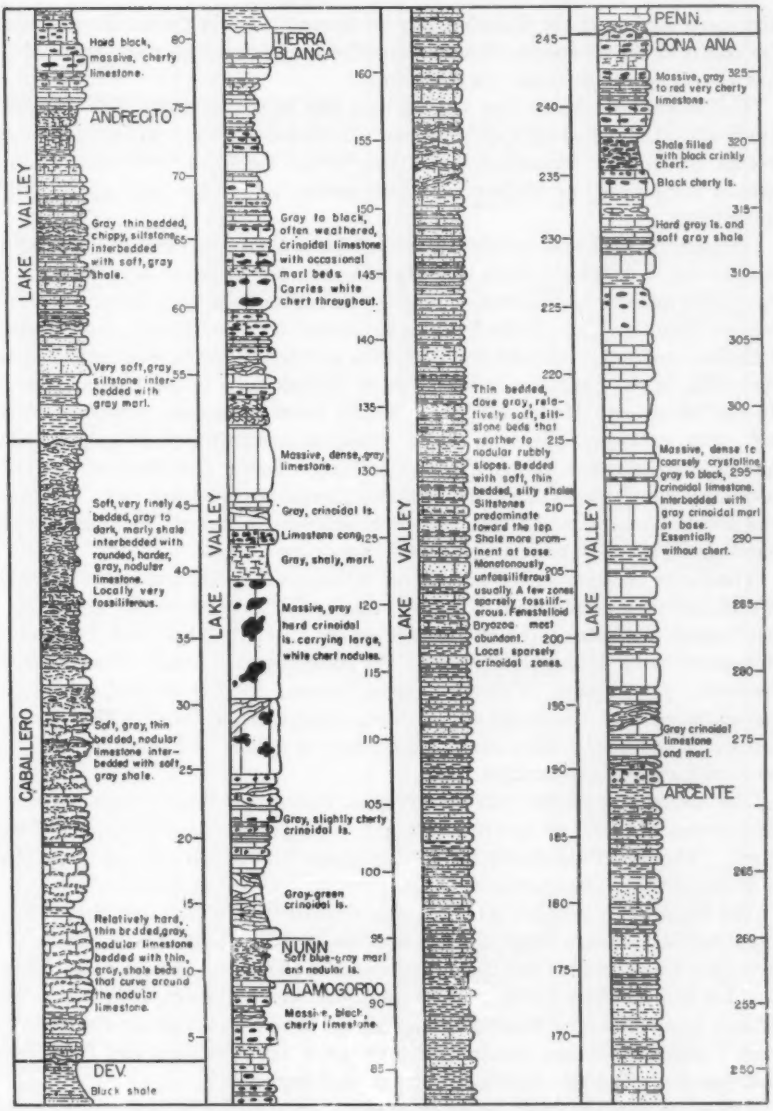
CABALLERO
LAKE VALLEY
Hard black, massive, cherty limestone.
ANDRECITO
Gray thin bedded, chippy, siltstone interbedded with soft, gray shale.
Very soft, gray siltstone interbedded with gray marl.
Soft, very finely bedded, gray to dark, marly shale interbedded with rounded, harder, gray, nodular limestone. Locally very fossiliferous.
Soft, gray, thin bedded, nodular limestone interbedded with soft gray shale.
Relatively hard, thin bedded, gray, nodular limestone bedded with thin, gray, shale beds that curve around the nodular limestone.
DEV.
Black shale
LAKE VALLEY
TIERRA BLANCA
Gray to black, often weathered, crinoidal limestone with occasional marl beds. Carries white chert throughout.
Massive, dense, gray limestone.
Gray, crinoidal ls.
Limestone cong.
Gray, shaly, marl.
Massive, gray hard crinoidal ls. carrying large, white chert nodules.
Gray, slightly cherty crinoidal ls.
Gray-green crinoidal ls.
NUNN
Soft blue-gray marl and nodular ls.
ALAMOGORDO
Massive, black, cherty limestone
LAKE VALLEY
Thin bedded, dove gray, relatively soft, siltstone beds that weather to nodular rubbly slopes. Bedded with soft, thin bedded, silty shales. Siltstones predominate toward the top. Shale more prominent at base. Monotonously unfossiliferous usually. A few zones sparsely fossiliferous. Fenestelloid Bryozoa most abundant. Local sparsely crinoidal zones.
LAKE VALLEY
PENN.
DONA ANA
Massive, gray to red very cherty limestone.
Shale filled with black crinkly chert.
Black cherty ls.
Hard gray ls. and soft gray shale
Massive, dense to coarsely crystalline gray to black, crinoidal limestone. Interbedded with gray crinoidal marl at base. Essentially without chert.
Gray crinoidal limestone and marl.
ARCENTE

FIGURE 12.—*Deadman Canyon section, Sacramento Mountains*

NW¼, Sec. 3, T 17 S, R 10 E.

exposures. The change in thickness may be due to relief on the upper surface of the Caballero, to relief on the Devonian surface, or to a combination of both. Relief on

the upper surface of the Caballero can be demonstrated in the northern exposures because in all the area north of San Andreas Canyon the basal members are persistent, and the changes in thickness are at the top.

The Sacramento Mountains are the best area in southwestern New Mexico for study of the complete Lake Valley section. All six members are excellently developed except the Nunn. Stratigraphic relations within the Lake Valley formation are greatly complicated by bioherm structure, particularly in the northern part of the mountains.

Because the Andrecito member often contains reworked materials from underlying formations, its lithologic character is variable over southwestern New Mexico. The Andrecito member is of constant lithology throughout the Sacramento Mountains, but not characteristic. In the Sacramento Mountains area, the soft, easily reworked Caballero sediments underlie the Andrecito member, while in most other parts of New Mexico the Andrecito member lies on various units of the Devonian section. In the Sacramento Mountains the Andrecito member consists predominantely of soft, gray, calcareous siltstone, similar in appearance to the underlying Caballero, but lacking its characteristic irregular bedding. Poorly developed and relatively obscure bedding results in weathered slopes covered with chips of rock. Because of the interbedded soft and more resistant layers, most exposures weather into alternately hard, rounded, projecting, and soft, retreating surfaces.

The Andrecito member is characterized throughout the Sacramento Mountains by the abundant occurrence of "*Taonurus caudagalli*." In an earlier report on the Sacramento Mountains (Laudon and Bowsher, 1941, p. 2126) this member was designated as the *Taonurus* siltstone. The occurrence of *Chonetes illinoisensis*, *Dictyoclostus fernglenensis*, *Tylothyris novamexicana*, *Spirifer rowleyi*, *Brachythyris suborbicularis*, and *Athyris lamellosa* indicates that it is early Osage. The virtual absence of Kinderhook types is additional evidence of a sharp break between the Caballero and Lake Valley formation.

The Andrecito member is 25–35 feet thick throughout the northern Sacramento Mountains. It thins toward the south and in Nigger Ed Canyon cannot be recognized. The basal Lake Valley beds in the Nigger Ed Canyon area are black, cherty limestones of the Alamogordo member.

The Alamogordo member is restricted in this paper to include only the persistent, massive, black, cherty limestone beds between the softer siltstones and marls of the overlying Nunn member and the soft siltstones of the underlying Andrecito member. Laudon and Bowsher (1941, p. 2125) included the Andrecito, Nunn, and Tierra Blanca members in the Alamogordo member. Where bioherms are developed, the central biohermal mass generally rises directly through both Nunn and Tierra Blanca members entirely displacing them from a normal sequence.

The Alamogordo member forms a persistent scarp in the Sacramento Mountains. Over most of the area it is sparsely fossiliferous, although minor amounts of fragmentary crinoid materials occur in all the beds. A few of the larger brachiopods such as *Dictyoclostus fernglenensis*, *Athyris lamellosa*, and *Spirifer rowleyi* are present.

The Alamogordo member is remarkably constant in thickness, ranging between 35 and 40 feet throughout most of the area. Wherever bioherms originate within the

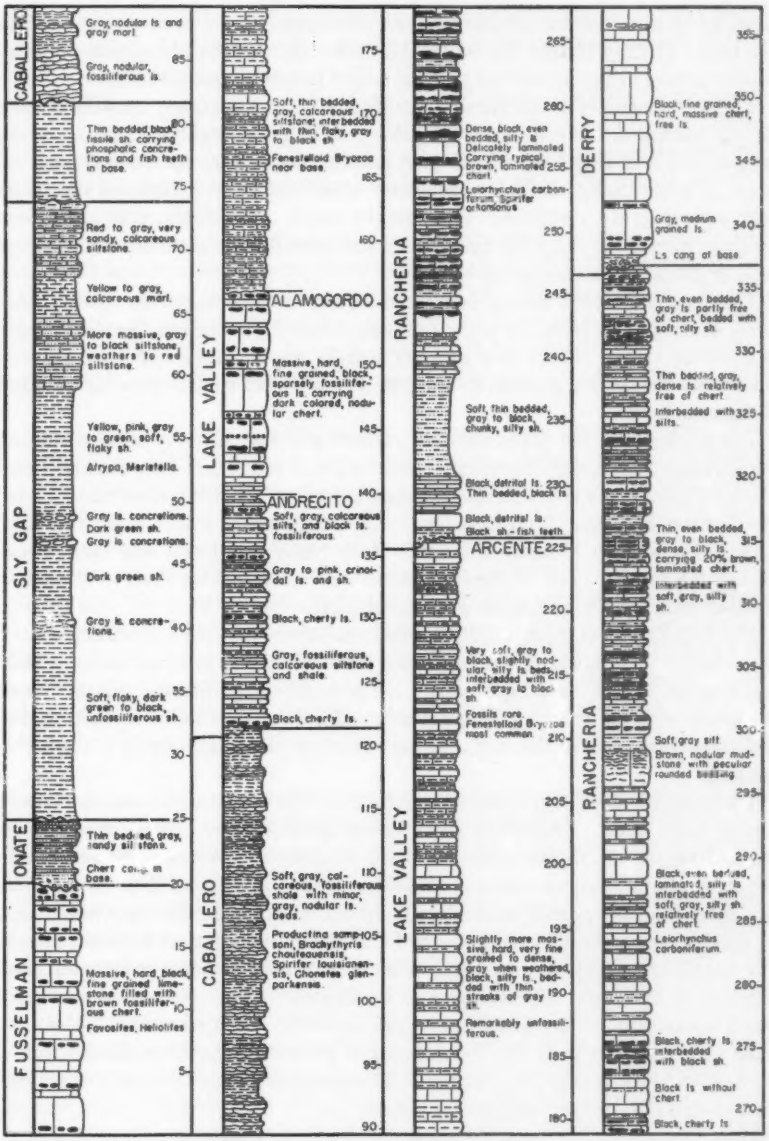
CABALLERO
Gray, nodular ls. and gray marl
Gray, nodular, fossiliferous ls.
Thin bedded, black, fissile sh. carrying phosphatic concretions and fish teeth in base.
Red to gray, very sandy, calcareous siltstone.
Yellow to gray, calcareous marl.
More massive, gray to black siltstone, weathers to red siltstone.
Yellow, pink, gray to green, soft, flaky sh.
Atrypa, Meristella.
Gray ls. concretions. Dark green sh. Gray ls. concretions.
Dark green sh.
Gray ls. concretions.
Soft, flaky, dark green to black, unfossiliferous sh.
Thin bedded, gray, sandy silt stone.
Chert conglm. at base.
Massive, hard, black, fine grained limestone filled with brown fossiliferous chert.
Favosites, Heliolites
SLY GAP
ONATE
FUSSELMAN
LAKE VALLEY
Soft, thin bedded, gray, calcareous siltstone; interbedded with thin, flaky, gray to black sh.
Fenestellaid Bryozoa near base.
ALAMOGORDO
Massive, hard, fine grained, black, sparsely fossiliferous ls. carrying dark colored, nodular chert.
ANDRECITO
Soft, gray, calcareous silts, and black ls. fossiliferous.
Gray to pink, crinoidal ls. and sh.
Black, cherty ls.
Soft, gray, calcareous, fossiliferous shale with minor, gray, nodular ls. beds.
Productina sampsoni, Brachythyris chauteauensis, Spirifer louisianensis, Chonetes glenparkensis.
CABALLERO
LAKE VALLEY
Dense, black, even bedded, silty & Delicately laminated Carrying typical, brown, laminated chert.
Leiorhynchus carboniferum, Spirifer arkansanus
Soft, thin bedded, gray to black, chunky, silty sh.
Black, detrital ls. Thin bedded, black ls
Black, detrital ls.
Black sh - fish teeth
ARCENTE
Very soft, gray to black, slightly nodular, silty ls. beds interbedded with soft, gray to black sh.
Fossils rare. Fenestellaid Bryozoa most common.
Slightly more massive, hard, very fine grained to dense, gray when weathered, black, silty ls., bedded with thin streaks of gray sh.
Remarkably unfossiliferous.
RANCHERIA
DERRY
Black, fine grained, hard, massive chert, free ls.
Gray, medium grained ls.
Ls cong at base
Thin, even bedded, gray ls partly free of chert, bedded with soft, silty sh.
Thin bedded, gray, dense ls relatively free of chert
Interbedded with silts.
Thin, even bedded, gray to black, dense, silty ls. carrying 20% brown, laminated chert.
Interbedded with soft, gray, silty sh.
Soft, gray silt
Brown, nodular mudstone with peculiar rounded bedding
Black, even bedded, laminated, silty ls interbedded with soft, gray, silty sh. relatively free of chert
Leiorhynchus carboniferum.
Black, cherty ls interbedded with black sh.
Black ls without chert
Black, cherty ls

FIGURE 13.—*Escondido Canyon section*

SE¼, Sec. 26, T 18 S, R 10 E.

member its thickness varies abruptly and has been observed to reach approximately 180 feet. It thins toward the south end of the Sacramento Mountains to approximately 15 feet in Escondido Canyon and only 5 feet in Nigger Ed Canyon.

The Nunn member in the Sacramento Mountains is exceedingly variable in character and thickness. It consists of soft, blue-gray to green, highly crinoidal, marl beds interbedded with thin-bedded, blue-gray criquina beds. The succession of marls and criquina is extremely variable within very short distances. Many of the criquina beds appear as discontinuous lenses in the marls. In the bioherm areas in the northern part of the range the marl beds grade laterally into massive, coarse, criquina beds on the lateral slopes of the bioherms.

The overlying Teirra Blanca member is mainly criquina in the Sacramento Mountains, which greatly complicates the problem of drawing boundaries between members in bioherm areas. The Nunn member usually grades slowly up into the Tierra Blanca member with a gradual thinning of the marls and a corresponding thickening of the criquinas.

The thickness of the Nunn member varies rapidly within very short distances in the northern Sacramento Mountains from as much as 120 feet near the lower end of Marble Canyon to less than a foot approximately half a mile up the Canyon. In all the northern area the Nunn member can be differentiated even though it generally makes only a shaly break in the cliff. Both Nunn and Dona Ana members thin toward the southern end of the mountains, and south of Dog Canyon the Arcente member rests directly on the Alamogordo member.

The Nunn member is prolifically fossiliferous throughout the northern Sacramento Mountains. The fauna is predominantly crinoidal, but in some areas is rich in brachiopods, corals, and bryozoans. Large numbers of brachiopods are usually associated with the crinoids. Remarkably well-preserved crinoids occur in the interbiohermal facies where the soft blue-gray marls of the Nunn member are best developed.

The prolific Lake Valley crinoid fauna occurs in the Nunn member at the type section at Lake Valley. Although Lake Valley specimens have been compared with species from the Burlington limestone, many of them are new species, primitive transitional forms of Burlington species. This part of the Lake Valley fauna is unquestionably older than any part of the Burlington formation of the Mississippi Valley. Similar species have been collected from the Fern Glen formation near Lithium, Missouri. The wealth of crinoids now available from New Mexico is aiding greatly our understanding of the origin and evolution of Burlington forms. Heretofore the gap between Kinderhook crinoids and Burlington species has been enormous. Most of the Lake Valley species from the Nunn member lie midway between Kinderhook and Burlington forms in stage of evolution. Discussion of such a fauna is difficult before specific description has been accomplished.

Most common in the fauna are numerous species of *Cactocrinus* (?) that appear to be transitional between *Actinocrinites* from the Chouteau and *Cactocrinus* from the lower Burlington. Other genera include *Steganocrinus*, *Eucladocrinus*, *Rhodocrinites*, *Dorycrinus*, *Macrocrinus*, *Uperocrinus*, *Barycrinus*, *Synbathocrinus*, and several species of *Platycrinites*.

Knowledge of crinoid faunas from pre-Burlington formations (Osage) in the Upper Mississippi Valley is limited but we recognize some species common to part of the Fern Glen of southeastern Missouri.

The Tierra Blanca member is well developed in all but the southern Sacramento Mountains. It has not been recognized in Escondido or Nigger Ed Canyon. The member consists of gray to brown, relatively thin-bedded, cherty criquina that invariably forms a conspicuous scarp along the mountain front. The chert is usually gray or white, rarely black.

The Tierra Blanca member varies rapidly in thickness near biohermal structures. In much of the northern Sacramento Mountains the upper parts of bioherms grade insensibly into the massive limestone beds of the Tierra Blanca member. In the Marble Canyon area it varies from 2 feet to 90 feet in a horizontal distance of less than a mile. In areas where the Tierra Blanca is thin the underlying Nunn is correspondingly thicker. The aggregate thickness of the two members appears constant.

The Tierra Blanca fauna consists mainly of fragmentary fossil remains. The larger brachiopods such as *Spirifer rowleyi*, *Dictyoclostus fernglenensis*, *Athyris lamellosa*, and *Cliothyridina obmaxima* are fairly common. Identifiable crinoids occur only occasionally. *Steganocrinus*, *Cactocrinus*, *Actinocrinites*, *Platycrinites*, and *Amphoracrinus* occur most frequently. The Tierra Blanca fauna is pre-Burlington.

The Arcente member is relatively soft, dove-gray, thin-bedded, calcareous siltstone, interbedded with thin streaks of soft, gray shale. The shale occurs mainly as partings between the siltstone beds except in the lower portion where it occasionally makes layers a foot thick. The siltstone beds average less than 6 inches near the base and are thicker in the upper part of the member. The Arcente member has the same color as the Caballero formation but the former is distinctly even-bedded and lacks the nodular nature of the Caballero. The Arcente member weathers to a rubbly, retreating slope.

The thickness of the Arcente member varies quite rapidly in the Sacramento Mountains but not as rapidly as the underlying Nunn and Tierra Blanca. In a few localities biohermal structures rise entirely through it. Maximum thickness is slightly over 230 feet at the type area in Deadman Canyon.

The Arcente member was thought to rest conformably on the underlying Tierra Blanca member (Laudon and Bowsher, 1941, p. 2135) but the rapid changes in thickness suggest marked unconformity. Recent studies of the contact indicate that the Arcente member rests disconformably on the underlying beds. Red oxidized zones are common at the base, and some evidence of solution occurs on the upper surface of the Tierra Blanca. The topmost surface of the Tierra Blanca at a few places is covered by silicified fossils, rare in the remainder of the member. Most conclusive, the Arcente in the southern part of the range overlaps onto lower and lower portions of the Lake Valley formation. In Escondido Canyon (Fig. 13) it rests on the upper part of the Alamogordo member, and in the Nigger Ed Canyon (Fig. 14) it lies on the thin lowermost beds of the Alamogordo.

The Arcente member is remarkably unfossiliferous throughout most of its area of outcrop. It contains many fenestelloid bryozoans on bedding planes, but the remain-

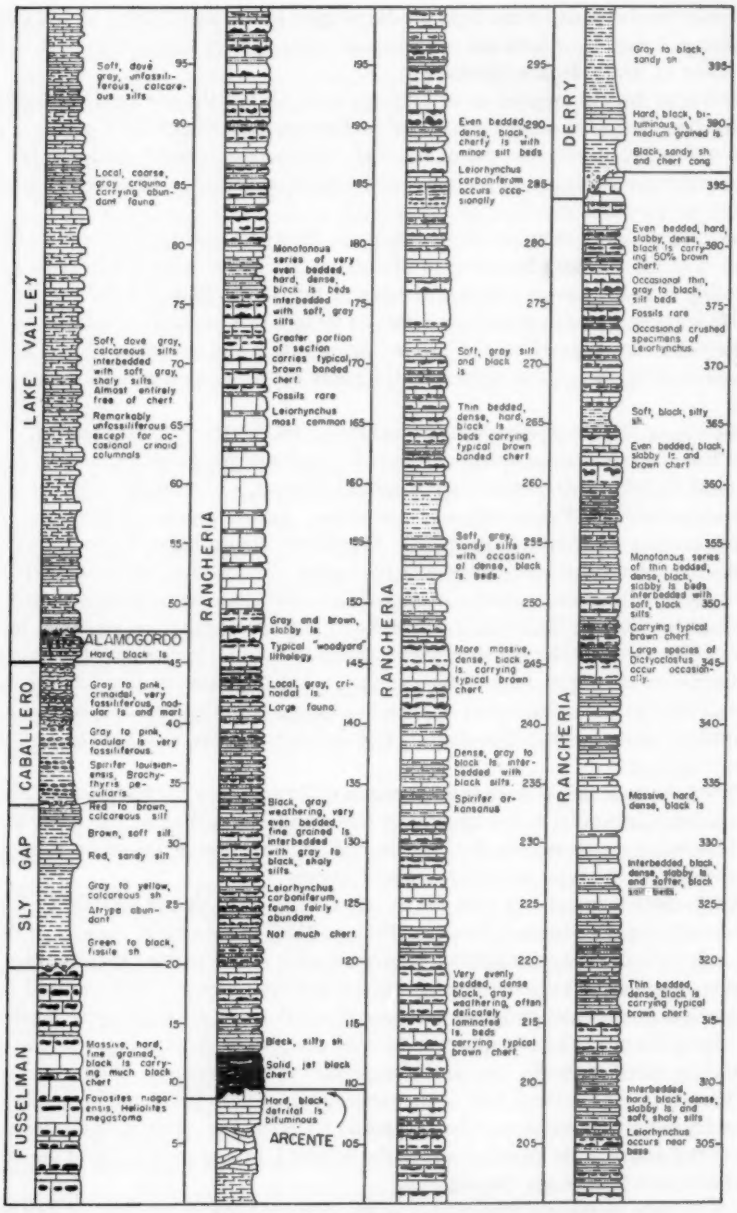
FUSSELMAN
SLY GAP
CABALLERO
LAKE VALLEY
RANCHERIA
RANCHERIA
RANCHERIA
DERRY
ALAMOGORDO
ARCENTE
Soft, dove gray, unfossiliferous, calcareous silts
Local, coarse, gray crinoina carrying abundant fauna
Soft, dove gray, calcareous silts interbedded with soft, gray, shaly silts. Almost entirely free of chert
Remarkably unfossiliferous except for occasional crinoid columnals
Hard, black ls
Gray to pink, crinoidal, very fossiliferous, nodular ls and mart
Gray to pink, nodular ls very fossiliferous
Spirifer lowensensis, Brachythyris peculiaris
Red to brown, calcareous silt
Brown, soft silt
Red, sandy silt
Gray to yellow, calcareous sh
Atrypa abundant
Green to black, fissile sh
Massive, hard, fine grained, black ls carrying much black chert
Favosites niagarensis, Heliolites megastoma
Monotonous series of very even bedded, hard, dense, black ls beds interbedded with soft, gray silts
Greater portion of section carries typical brown banded chert
Fossils rare
Leiorhynchus most common
Gray and brown, slabby ls
Typical "woodyard" lithology
Local, gray, crinoidal ls
Large fauna
Black, gray weathering, very even bedded, fine grained ls interbedded with gray to black, shaly silts
Leiorhynchus carboniferum, fauna fairly abundant
Not much chert
Black, silty sh
Solid, jet black chert
Hard, black, detrital ls bituminous
Even bedded, dense, black, cherty ls with minor silt beds
Leiorhynchus carboniferum occurs occasionally
Soft, gray silt and black ls
Thin bedded, dense, hard, black ls beds carrying typical brown banded chert
Soft, gray, sandy silts with occasional dense, black ls beds
More massive, dense, black ls carrying typical brown chert
Dense, gray to black ls interbedded with black silts
Spirifer arkansanus
Very evenly bedded, dense black, gray weathering, often delicately laminated ls beds carrying typical brown chert
Gray to black, sandy sh
Hard, black, bituminous ls medium grained ls
Black, sandy sh and chert cong
Even bedded, hard, slabby, dense, black ls carrying 50% brown chert
Occasional thin, gray to black, silt beds
Fossils rare
Occasional crushed specimens of Leiorhynchus
Soft, black, silty sh
Even bedded, black, slabby ls and brown chert
Monotonous series of thin bedded, dense, black, slabby ls beds interbedded with soft, black silts
Carrying typical brown chert
Large species of Dictyoclostus occur occasionally
Massive, hard, dense, black ls
Interbedded, black, dense, slabby ls and softer, black silt beds
Thin bedded, dense, black ls carrying typical brown chert
Interbedded, hard, black, dense, slabby ls and soft, shaly silts
Leiorhynchus occurs near base

FIGURE 14.—*Nigger Ed Canyon section*

NE¼, NW¼, Sec. 18, T 18 S, R 11 E.

der of the faunal elements are rare. Small corals such as *Cyathaxonia arcuatus* and *Zaphrentis cliffordana* are common. Isolated exposures have yielded a few crinoids, including *Steganocrinus*, *Cactocrinus*, and *Platycrinites*. The brachiopod fauna is characteristically early Osage. *Chonetes* cf. *C. glenparkensis*, *Dictyoclostus fernglenensis*, *Rhipidomella missouriensis*, *Spirifer platynotus*, and *Cliothyridina glenparkensis* are the most common forms. This fauna would definitely be considered as older than upper Burlington.

The Dona Ana consists of relatively massive, gray to brown, occasionally almost black, very crinoidal limestone filled with large, white to gray chert masses. The upper part is particularly cherty. It normally crops out in bold escarpments along the mountain front. It is far less extensive than any other member of the Lake Valley formation. In the northern part of the range, its limited distribution is apparently due to pre-Pennsylvanian erosion, while in the south it was either removed by erosion before the deposition of the Rancheria formation or never deposited. It cannot be recognized in either Escondido or Nigger Ed Canyon. The Member attains a maximum thickness of 175 feet between Mule and San Andres canyons.

The Dona Ana is fossiliferous throughout although the fossils are mainly fragmentary. Good collections can be made at most exposures. The occurrence of *Eutrochcorinus christyi*, *Eretmocrinus remibranchiatus*, *Agaricocrinites planoconvexus*, *Agaricocrinites excavatus*, and *Physetocrinus ventricosus* with typical specimens of *Spirifer grimesi* indicates Burlington age for the Dona Ana member. None of the typical upper Burlington species that characterize the Mississippi Valley area occur in the fauna. The stage of evolution indicated by the fauna is pre-upper Burlington.

The Rancheria formation overlaps the underlying Osage beds with marked unconformity in the southern portion of the Sacramento Mountains. Almost the entire Lake Valley formation is truncated in the southern part. The contact everywhere shows evidences of an unconformity, in angular contact, reworked materials, "phosphatic" concretions, and oxidized zones.

The Rancheria formation (Fig. 14) is a monotonous, evenly-bedded sequence of dove-gray to brownish-gray, slightly calcareous siltstone carrying considerable amounts of brown, crinkly, secondary chert (?), rhythmically bedded with thin shale partings. The beds are rarely more than a foot thick. A few of the basal shale beds are as much as 5 feet thick. The maximum thickness is slightly over 275 feet in the southern part of the range.

A few poorly preserved fossils occur sporadically in the Rancheria formation, but most of the sequence appears to be without fossils. *Leiorhynchus carboniferum* is most abundant; *Spirifer arkansanus* and *Dictyoclostus inflatus* var. *coloradoensis* occur sporadically. A localized limestone bioherm occurs just south of Escondido Canyon, where a large fauna was collected.

HUECO MOUNTAINS

Summary.—No rocks of Caballero, Lake Valley, or Kelly age are exposed in the Hueco or Franklin mountains (Fig. 11). In the Hueco Mountains the Rancheria formation rests unconformably on Devonian rocks. The Rancheria formation is unconformably overlain by the Helms formation of Chester age. The Helms forma-

tion is overlain by rocks of Pennsylvanian age with marked unconformity. Evidence of relief on the Mississippian surface is marked in both areas.

General description.—Mississippian rocks were first identified in the Hueco Mountains by Beede (1920, p. 8). It is apparent from his descriptions that he included different divisions in his Helms beds which we are placing in the Rancheria and Helma (restricted). He identified fossils from the Helms as Chester.

The Helms in the Hueco Mountains was again described by P. B. King and R. E. King (1929, p. 909). They included strata in the Helms which we would place in the Helms (restricted), the Rancheria, the Canutillo formations and the chert which underlies the latter. They concluded that "This upper member contains Chester fossils but the behavior of the three members leads one to suspect that the group is not a single unit but may contain beds of several ages."

Detailed information on the stratigraphy of the Mississippian rocks in the Hueco Mountains was published in an areal map by P. B. King and J. B. Knight (1945, sheet 2) and by P. B. King, R. E. King and J. B. Knight (1945, sheet 1). Six sections showing Devonian and Mississippian rocks in the Hueco Mountains are diagrammed. The Helms is divided into a lower member of shales and cherty limestones, assigned to the Meramec and an upper member of silty limestones at the base overlain by shales and limestones assigned to the Chester.

The division between the lower and upper members of the Helms formation as shown by King and Knight falls in the central part of the Rancheria formation as defined in this paper. Moorefield (Meramec) fossils were collected by us from the silty beds in the base of the upper member as described by King and Knight. Chester fossils do not occur below the shaly upper part of their upper member.

Mississippian rocks crop out along the west face of the Hueco Mountains from section 15, Blk. 77, T. 1, southward to section 7, School Blk, 10, 4 miles south of Rancheria Peak. Over much of this area only partial sections are exposed but a fairly complete section occurs about a mile south of Helms Peak where Canutillo beds containing abundant Devonian fossils are overlain by nearly 200 feet of Rancheria. Here the Rancheria is capped by shales, sands, and thin limestone beds having a Chester fauna.

Rancheria Peak section.—The Rancheria Peak section (Fig. 15) (center section 7, S. Blk. 9, El Paso County, Texas) is the most completely exposed in the Hueco Mountains. Mississippian rocks lie along the southwestern face of Rancheria Peak for a distance of several miles and several steep gully washes make available study on a complete section.

In this area, the Fusselman limestone is overlain by approximately 30 feet of massive, coarsely crystalline, pink to gray limestone with large calcareous algae, lithologically similar to the Chimney Hill (Silurian) formation of the Arbuckle Mountains of Oklahoma (Reeds, 1911, p. 256). These granular limestones are almost free of chert and are quite unlike the underlying Fusselman. No specific age is assigned to them in this report.

The pink crystalline limestones are unconformably overlain by nodular, yellow to brown, extremely cherty limestone beds, slightly over 100 feet thick. Chert, thin-bedded and nodular, generally makes up as much as 90 per cent of the formation. No

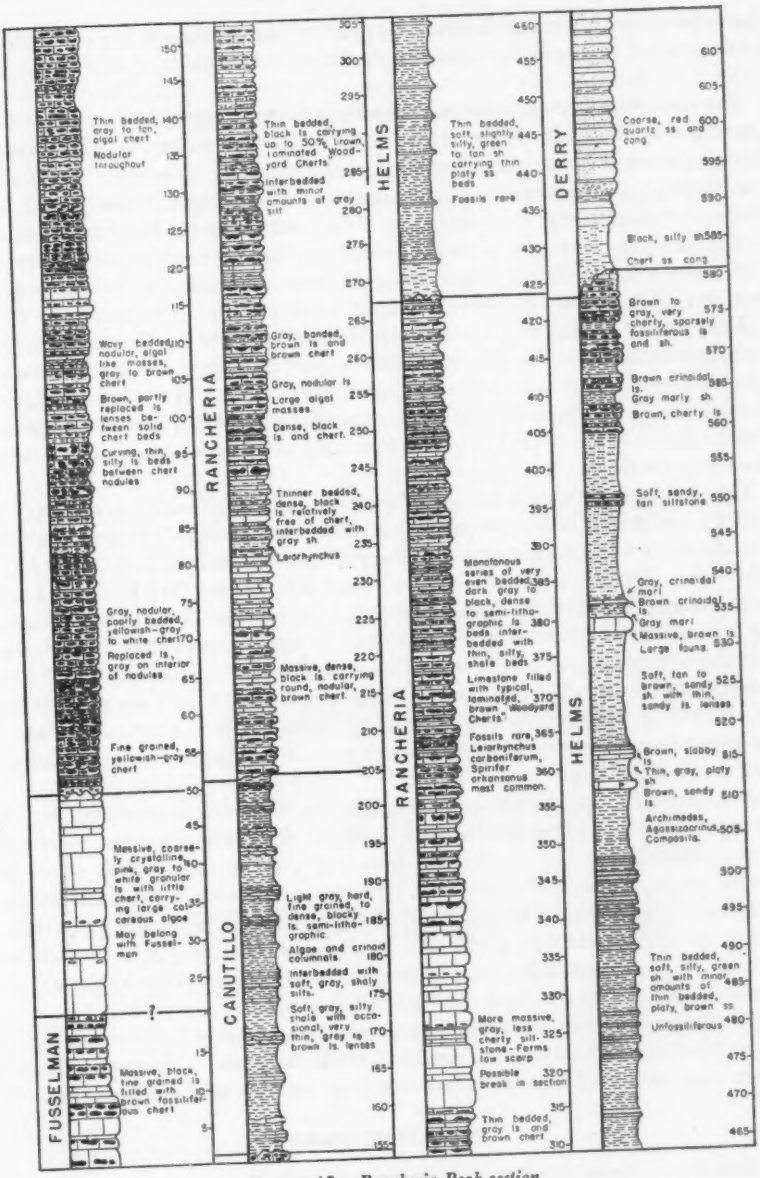
FUSSELMAN
CANUTILLO
RANCHERIA
HELMS
RANCHERIA
DERRY
HELMS
Thin bedded, gray to tan, algal chert
Nodular throughout
Wavy bedded, nodular, algal like masses, gray to brown chert
Brown, partly replaced ls lenses between solid chert beds
Curving, thin, silty ls beds between chert nodules
Gray, nodular, poorly bedded, yellowish-gray to white chert
Replaced ls, gray on interior of nodules
Fine grained, yellowish-gray chert
Massive, coarsely crystalline, pink, gray to white granular ls with little chert, carrying large calcareous algae
May belong with Fusselman
Massive, black, fine grained ls filled with brown fossiliferous chert
Thin bedded, block ls carrying up to 50% brown, laminated "Woodyard Cherts"
Interbedded with minor amounts of gray silt
Gray, banded, brown ls and brown chert
Gray, nodular ls
Large algal masses
Dense, black ls and chert
Thinner bedded, dense, black ls relatively free of chert, interbedded with gray sh
Leorhynchus
Massive, dense, black ls carrying round, nodular, brown chert
Light gray, hard, fine grained, to dense, blocky ls, semi-lithographic
Algae and crinoid columnals
Interbedded with soft, gray, shaly silts
Soft, gray, silty shale with occasional, very thin, gray to brown ls lenses
Thin bedded, soft, slightly silty, green to tan sh carrying thin platy ss beds
Fossils rare
Monotonous series of very even bedded, dark gray to black, dense to semi-lithographic ls beds interbedded with thin, silty, shale beds
Limestone filled with typical, laminated, brown "Woodyard Cherts"
Fossils rare, Leorhynchus carboniferum, Spirifer arkansanus most common.
More massive, gray, less cherty silt-stone - Forms low scarp
Possible break in section
Thin bedded, gray ls and brown chert
Coarse, red quartz ss and cong
Black, silty sh
Chert ss cong
Brown to gray, very cherty, sparsely fossiliferous ls and sh
Brown crinoidal ls
Gray marly sh
Brown, cherty ls
Soft, sandy, tan siltstone
Gray, crinoidal marl
Brown crinoidal ls
Gray marl
Massive, brown ls
Large fauna
Soft, tan to brown, sandy sh with thin, sandy ls lenses
Brown, slabby ls
Thin, gray, platy sh
Brown, sandy ls
Archimedes, Agassizocrinus, Composita
Thin bedded, soft, silty, green sh with minor amounts of thin bedded, platy, brown ss
Unfossiliferous

FIGURE 15.—*Rancheria Peak section*

Center Sec. 7, S. Blk. 9, El Paso Co., Texas. (The mountain designated as Rancheria Peak in this report lies approximately 4½ miles NW of Rancheria Peak (King and Knight, 1945). This section and part of the accompanying text were prepared prior to the publication of the map by King and Knight.)

fossils have been found in this formation in either the Franklin or Hueco Mountains. Lithologically, it is probably most like the Caballos novaculite of west Texas (P. B. King, 1937, p. 47).

The chert beds are unconformably overlain by soft, gray, silty shales, and silty limestones of the Cantuillo formation. The upper part of the Canutillo formation contains lenses of dense, hard, light-gray, semilithographic limestone. It is sparcely fossiliferous but does contain *Leiorhynchus*, and a few linguloid brachiopods, both similar to forms found at the type section of the Canutillo in the Franklin Mountains.

The Canutillo formation is unconformably overlain by the Rancheria formation. The contact is sharply unconformable, fish teeth, "phosphatic" concretions, and local sand lenses occur just above the contact. No beds of Caballero, Lake Valley, or Kelly age have been found in the Hueco Mountains. The Las Cruces formation so well represented in the Franklin Mountains a short distance to the west has not been identified, although a thin, semilithographic limestone bed at the base of the Rancheria immediately south of Helms Peak may represent the Las Cruces. A species of *Proetus* similar to one in the Las Cruces formation at the type area was found in limestone float south of Helms Peak.

The Rancheria formation consists of monotonously thin-bedded, gray, silty limestones interstratified with thin gray shale. The beds average 7 inches in thickness and are rarely over 18 inches thick. The shale partings are generally under half an inch thick. The entire section is filled with elongate, slender, "crinkly," and nodular chert masses that ordinarily make up as much as 50 per cent of the rocks. Weathering of these cherts produces rich brown, angular rock chips causing the outcrop to resemble a woodyard, hence the name "Woodyard cherts" (Beede, 1920). The Rancheria is slightly over 215 feet thick at Rancheria Peak. Fossils are rare but occur occasionally in the basal beds. A few occur sporadically throughout the section. *Leiorhynchus carboniferum*, *Spirifer arkansanus* and *Dictyoclostus inflatus* var. *coloradoensis* are most common.

The Helms formation (restricted) overlies the Rancheria unconformably. The lower beds consist of green, thin-bedded, "chippy" shales with very thin, "waferlike" brown sand lenses. The middle part consists of gray to brown, sandy shales with several brown, slabby limestone beds. The limestone beds and associated marls carry excellent faunas. The upper beds consist mainly of brown, cherty, crinoidal limestones interbedded with gray marls. The fauna contains typical Chester forms such as *Archimedes terebriformis*, *Diaphragmus elegans*, *Spiriferina transversa*, *Composita subquadrata*, and several species of *Dictyoclostus*.

The Helms formation is unconformably overlain by early Pennsylvanian rocks. In the Rancheria Peak area they consist of sands and shales. Farther north in the Helms Peak area, the Mississippian is overlain by Pennsylvanian limestone beds.

FRANKLIN MOUNTAINS

Summary.—Mississippian rocks are exposed west of the crest of the Franklin Mountains on the dip slope of the fault block. Good exposures are found straight east of Vinton, Texas. No Caballero, Lake Valley, or Kelly rocks have yet been found in these exposures (Fig. 16). The Las Cruces formation, the oldest Missis-

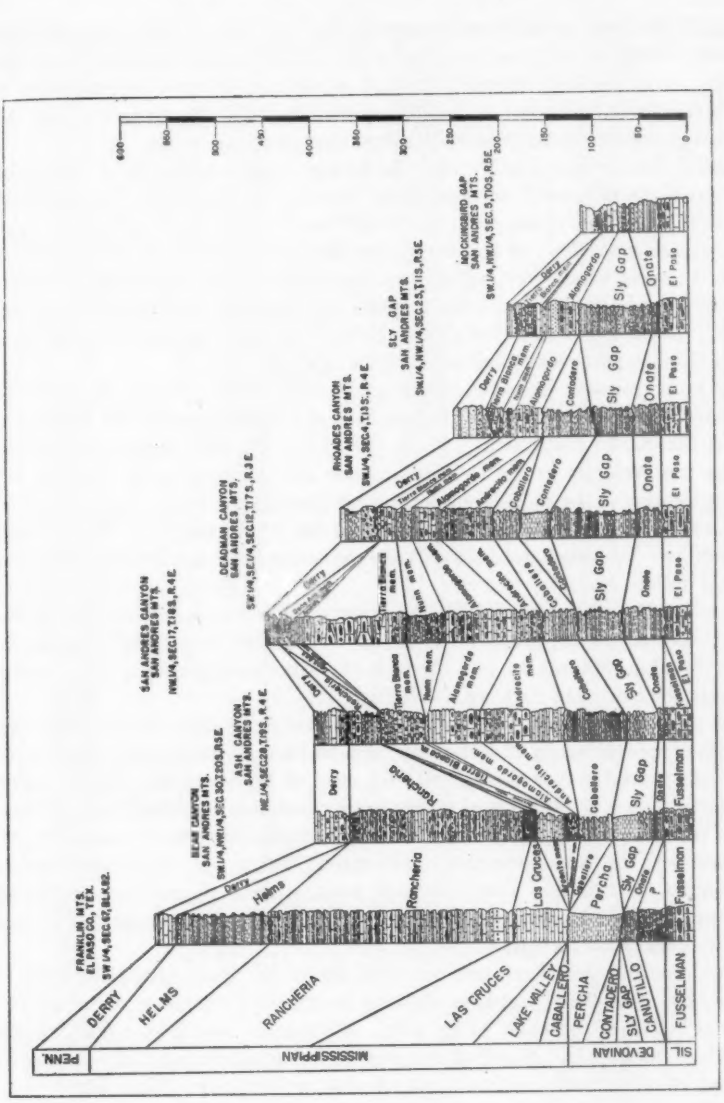

FIGURE 16.—*Correlation of sections—Franklin and San Andres mountains*

sippian in the area, unconformably overlies the Canutillo (?) formation and unconformably underlies the Rancheria formation. The Rancheria formation is unconformably overlain by the Helms formation which is in turn unconformably overlain by the La Tuna formation of the Pennsylvanian. The top surface of the Helms strata is of moderate relief produced by pre-Pennsylvanian erosion.

General description.—The Franklin Mountains consist primarily of a fault block with pre-Cambrian rocks exposed along the east face and with the sedimentary section tilted steeply to the west. Dips over most of the area approach 45 degrees.

Along the west slope of the mountains the soft Canutillo formation has been eroded to make a valley extending from the northern end to the area immediately west of Fusselman Canyon, with a steep, well-exposed Mississippian escarpment above. In the southern end of the Franklin Range, river gravels cover the area in which Mississippian rocks would normally be exposed.

The most complete section of Mississippian rocks in the Franklin Mountains was measured by Nelson (1940, p. 165) at the head of a small canyon in the SW¼, Sec. 67, School Blk. 82, El Paso County, Texas (Fig. 17). The Mississippian strata in this section were referred to the Helms formation and assigned to the Chester. Best exposures occur in the saddle south of the gap through the Pennsylvanian limestone. In this area the Fusselman limestone makes the main axial ridge of the Franklin Mountains. Devonian and Mississippian formations crop out far down the western slope of the mountains.

Franklin Mountain section.—The Fusselman formation is overlain by 42 feet of very cherty limestone, probably Devonian. No fossils were found in these cherts of the Franklin Mountains, but cherts in the same stratigraphic position were referred to the Devonian by King (1945, Sheet 2).

The cherts are overlain by the Canutillo formation (Nelson, 1940, p. 164), which consists of approximately 15 feet of soft, thin-bedded, gray siltstone. The Canutillo formation is fossiliferous throughout, but most of the forms are of little value for correlation. A species of *Leiorhynchus* is most common. Several linguloid brachiopods and a few pelecypods were collected. Lithologically, the formation is almost identical with the Onate formation of Stevenson (1945, p. 222) in the Sacramento and San Andres Mountains. These lithologic features are so distinctive over the whole southwestern New Mexico area that we correlate the Canutillo formation, at least in part, with the Onate formation.

The Canutillo formation is overlain by 57 feet of soft, flaky, gray-black shale. No fossils have been found but it is identical in lithologic character with part of the "Percha" shale of the Lake Valley area. We suspect that it should be correlated with the Percha shale. Shales of this type do not occur in Onate, Sly Gap, or Contadero formations to the north in the San Andres or Sacramento Mountains.

No Lake Valley or Kelly rocks occur in the Franklin Mountains. Strata tentatively correlated with the Lake Valley formation by King (1934, p. 1540) lie at the base of the Rancheria formation and contain the *Leiorhynchus carboniferum* fauna. These beds consist of dirty, gray to black, detrital crinoidal limestone and are lithologically quite different from the crinoidal limestone beds of the Lake Valley formation.

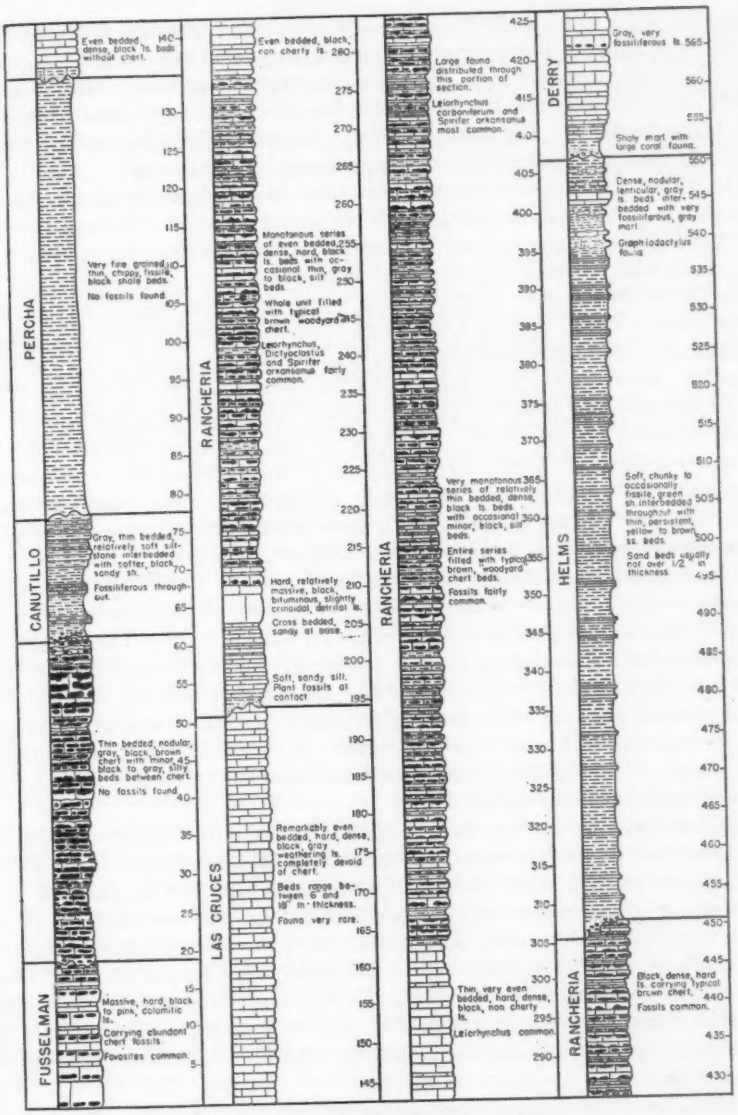
FUSSELMAN
CANUTILLO
PERCHA
LAS CRUCES
RANCHERIA
RANCHERIA
DERRY
HELMS
RANCHERIA
Massive, hard, black to pink, dolomitic ls.
Carrying abundant chert fossils
Fossils common.
Thin bedded, nodular, gray, black, brown chert with minor black to gray, silty beds between chert.
No fossils found.
Gray, thin bedded, relatively soft siltstone interbedded with softer, black, sandy sh.
Fossiliferous throughout.
Very fine grained, thin, chippy, fissile, black shale beds.
No fossils found.
Even bedded, dense, black ls. beds without chert.
Soft, sandy silt. Plant fossils at contact
Cross bedded, sandy at base.
Hard, relatively massive, black, bituminous, slightly crinoidal, detrital ls.
Leiorhynchus, Dictyoclostus and Spirifer arcuatus fairly common.
Whole unit filled with typical brown woodyard chert.
Monotonous series of even bedded, dense, hard, black ls. beds with occasional thin, gray to black, silty beds.
Even bedded, black, non cherty ls.
Remarkably even bedded, hard, dense, black, gray weathering ls. completely devoid of chert.
Beds range between 6" and 18" in thickness.
Fauna very rare.
Thin, very even bedded, hard, dense, black, non cherty ls.
Leiorhynchus common.
Very monotonous series of relatively thin bedded, dense, black ls. beds with occasional minor, black, silt beds.
Entire series filled with typical brown woodyard chert beds.
Fossils fairly common.
Large fauna distributed through this portion of section.
Leiorhynchus carboniferum and Spirifer arkansanus most common.
Black, dense, hard ls. carrying typical brown chert.
Fossils common.
Soft, chunky to occasionally fissile, green sh. interbedded throughout with thin, persistent, yellow to brown ss. beds.
Sand beds usually not over 1/2" in thickness.
Dense, nodular, lenticular, gray ls. beds interbedded with very fossiliferous, gray marl.
Graptoidactylus fauna
Shaly marl with large coral fauna.
Gray, very fossiliferous ls.

FIGURE 17.—*Franklin Mountains section*

SW¼, Sec. 67, S. Blk. 82, El Paso Co., TEXAS.

LAS CRUCES FORMATION: The Las Cruces formation, dense, sublithographic, remarkably evenly bedded, black, limestone (gray when weathered), lying unconformably on the "Percha" shale and is overlain unconformably by the Rancheria

formation in the Franklin Mountains. The Las Cruces formation is 59 feet thick at the type section. It is very sparsely fossiliferous, and because of its hardness, identifiable specimens are rare. Trilobite fragments are common. The following fossils were identified from the Las Cruces formation at the type area: *Zaphrentis* sp., *Linoproductus* sp., *Dictyoclostus inflatus*, *Spirifer* cf. Sp. *subaequalis*, *Eumetria acuticosta*, *Aviculopecten interlineatus*, *Straparolus* sp., and *Proetus* sp.

This fauna inconclusively suggests that these Mississippian strata are younger than Osage. The Las Cruces formation is considered Meramec in this paper because it is lithologically similar to the overlying Rancheria formation and because it lies in the same basin occupied by Meramec formations.

RANCHERIA FORMATION: The formation, a gray to brown, cherty limestone, lies unconformably above the Las Cruces formation and unconformably beneath the green shales of the Helms formation in the Franklin Mountains. The type section is located at the same locality as the type section of the Las Cruces formation ($SW\frac{1}{4}$, Sec. 67, S. Blk. 82, El Paso Co., Texas). At the type area the Rancheria formation is approximately 255 feet thick. The basal portion differs lithologically from the rest of the formation. The basal beds consist of quartz sandstone containing carbonaceous plant remains and phosphatic concretions. These basal quartzose sandstones grade upward into soft, poorly consolidated, gray siltstones that contain abundant *Leiorhynchus carboniferum*. The gray siltstones grade upward into massive, black, speckled, detrital, bituminous limestone beds. The latter form a conspicuous scarp at the base of the Rancheria formation. It is apparent that these are the beds which King (1934, p. 1540) originally thought to be of Lake Valley age.

The Rancheria formation is predominantly gray, relatively thin-bedded, silty limestones from 4 to 24 inches thick. The upper part presents a monotonously even-bedded appearance. The bedding ordinarily consists of laminations of gray shale that generally thicken to several inches. Weathered surfaces are invariably rusty brown. These strata contain rusty brown, nodular chert lenses that generally make up more than 50 per cent of the rock.

Fossils are not abundant but occur along bedding planes and scattered throughout the formation. At the type area the upper beds are most fossiliferous. The following species have been identified from the Rancheria formation at the type area: *Zaphrentis* sp., *Pennirelepora* sp., *Dictyoclostus inflatus* var. *coloradoensis*, *Dictyoclostus tenuicostata*, *Dictyoclostus scitulus*, *Dictyoclostus* sp., *Productella moorefieldana*, *Productella* sp., *Avonia* sp., *Linoproductus pileiformis*, *Rhipidomella* sp., *Schizophoria* sp., *Leiorhynchus carboniferum*, *Spirifer* sp., *Spirifer* cf. sp. *leidyi*, *Spirifer arkansanus*, *Martinia glabra*, *Martinia* sp., *Reticularia* sp., *Syringothyris* sp., *Ambocoelia* sp., *Camarotoechia purduei* var. *agrestis*, *Deltopecten batesvillensis*, *Pleurotomaria* sp., and *Platyceras* sp.

Many species in the fauna are undescribed and must be compared only provisionally to known species. The forms are comparable to species in the Moorefield and Batesville faunas of the Ozark area. Since both fauna and lithologic characteristics are so strikingly like those of the Moorefield, we do not hesitate to make this correlation.

HELMS FORMATION: The lower 90 feet of the Helms formation is poorly fossiliferous, soft, flaky, green-weathering shale with very thin, platy, brown sandstone beds. The upper 8 feet is calcareous and contains nodular, fossiliferous, gray, limestone lenses.

Pentremites, Archimedes, Diaphragmus, and *Composita* occur abundantly in the upper part. The calcareous shales contain *Graphiodactylus arkansanus.* These species indicate Chester age.

ORGAN MOUNTAINS

Mississippian rocks crop out at intervals along the western slope of the Organ Mountains. Because of complex folding and faulting, complete sections are missing. Mississippian rocks can be identified in the area immediately south of St. Augustine Pass. In no case are the sections complete enough to be of particular value. Because of rapid thinning of the Lake Valley formation toward the south, it is doubtful if rocks of Lake Valley age are present in the southern part of the Organ Mountains. Altered rocks of Lake Valley age are present in the Organ mining district.

SAN ANDRES MOUNTAINS

Summary.—In the San Andres Mountains nearly 80 miles of almost uninterrupted exposure of Mississippian rocks offer an unusual opportunity to study lateral variations in Mississippian strata in a north-south direction. Caballero sediments thin toward the south and are not present in the northern part of the range (Fig. 16). In the intervening area they vary in thickness with evidence indicating relief both at the base and top of the formation. The Andrecito member of the Lake Valley formation thins both to the north and south and is missing in the northern part of the range. In the intervening area it varies in thickness with evidence indicating relief only at the base. The Andrecito member appears to grade insensibly upward into the Alamogordo member and in many areas is distinguishable only arbitrarily. The Alamogordo member, the most widespread and persistent part of the Lake Valley formation, retains its lithologic identity and average thickness throughout the San Andres range. It overlaps farthest to the north and eventually rests directly on the Devonian surface. The Nunn member, present in all except the northernmost exposures in the San Andres range, is variable in thickness, particularly in the vicinity of biohermal structures. In general it is less well developed than in the Lake Valley area to the west. The Tierra Blanca member thins toward the south as a result of nondeposition or pre-Arcente erosion. It is missing in the northernmost exposures, due in this case to pre-Pennsylvanian erosion. Throughout the central part of the range it forms bold steep cliffs that often cap the range. Arcente and Dona Ana sediments, present only in the southern and central portions of the ranges, are thinly developed wherever present, apparently because of both nondeposition and pre-Pennsylvanian erosion. Kelly strata were not found in the San Andres Mountains. The Las Cruces formation overlaps toward the north and is present only in the southernmost part of the range in Bear Canyon. The Rancheria formation also

overlaps toward the north and is present only as far north as Ash Canyon. Rocks of Helms age are not present. The pre-Pennsylvanian erosion surface was developed with remarkable relief, causing spectacular channel fills in some areas. Concentrations of reworked chert in the basal Pennsylvanian rocks suggest an eroding area to the west as a source area of chert since such conglomerates are of local extent to the east in the Sacramento Mountains.

General description.—The San Andres Mountains consist of a tilted fault block with the dissected scarp facing east toward the Tularosa Basin. Pre-Cambrian rocks lie at the base of the scarp over most of the distance between St. Augustine Pass and Mockingbird Gap. Sedimentary rocks ranging from Ordovician to Permian dip westward at low angles toward the Jornada Del Muerto. Mississippian rocks commonly cap the highest part of the range. The region is difficult of access.

Mississippian stratigraphy of the San Andres Mountains is similar to that of the Sacramento Mountains. Since the San Andres Mountains lie farther north toward Mississippian shore lines, the Lake Valley strata gradually pinch out in the north end. The gradual thinning and eventual shoreward limit of Lake Valley rocks cannot be seen in the Sacramento Mountains because the Mississippian rocks plunge beneath the valley floor in the vicinity of La Luz. The Las Cruces, Rancheria and Helms formations resemble closely those in the type section and thin out northward in the southern San Andres.

Bear Canyon section.—Bear Canyon (Fig. 18) is the first deep re-entrant into the San Andres Mountains north of the structurally complex area of the Organ Mining District. Excellent sections of Ordovician, Silurian, Devonian, Mississippian Pennsylvanian, and Permian rocks are exposed along the walls of Bear Canyon and along the walls of the small creek that drains westward toward the Jornada Del Muerto. The occurrence of excellent faunas in the Montoya formation is unusual *Streptelasma corniculum, Hebertella occidentalis, Dalmanella emacerata, Glyptorthis insculpta,* and *Rhynchotrema capax* were identified. They appear to represent a Cincinnatian fauna.

Mississippian rocks are best exposed in a small graben on the north side of Bear Canyon about a mile below the main (northern) tributary. A series of faults on the west side drops the succession lower and lower until the top of the Lake Valley formation lies against the Fusselman limestone on the west side of the fault zone. On the east side of the graben the Lake Valley rests against the Ordovician.

The Devonian section consists of about 15 feet of Onate silts at the base, overlain by shales and calcareous marls of the Sly Gap formation.

In Bear Canyon the Caballero formation lies at the base of the Mississippian section. Approximately 12 feet of soft, nodular, gray limestones and intercalated gray shales are all that can be referred to the Caballero formation. Typical Caballero fossils such as *Rhipidomella missouriensis, Spirifer louisianensis, Chonetes glenparkensis, Avonia boonensis, Productella concentrica,* and *Dictyoclostus arcuatus* were collected.

The Andrecito member of the Lake Valley formation rests unconformably on the Caballero formation in Bear Canyon. The contact is discernible with difficulty because the soft Caballero shales have been reworked into the basal beds of the

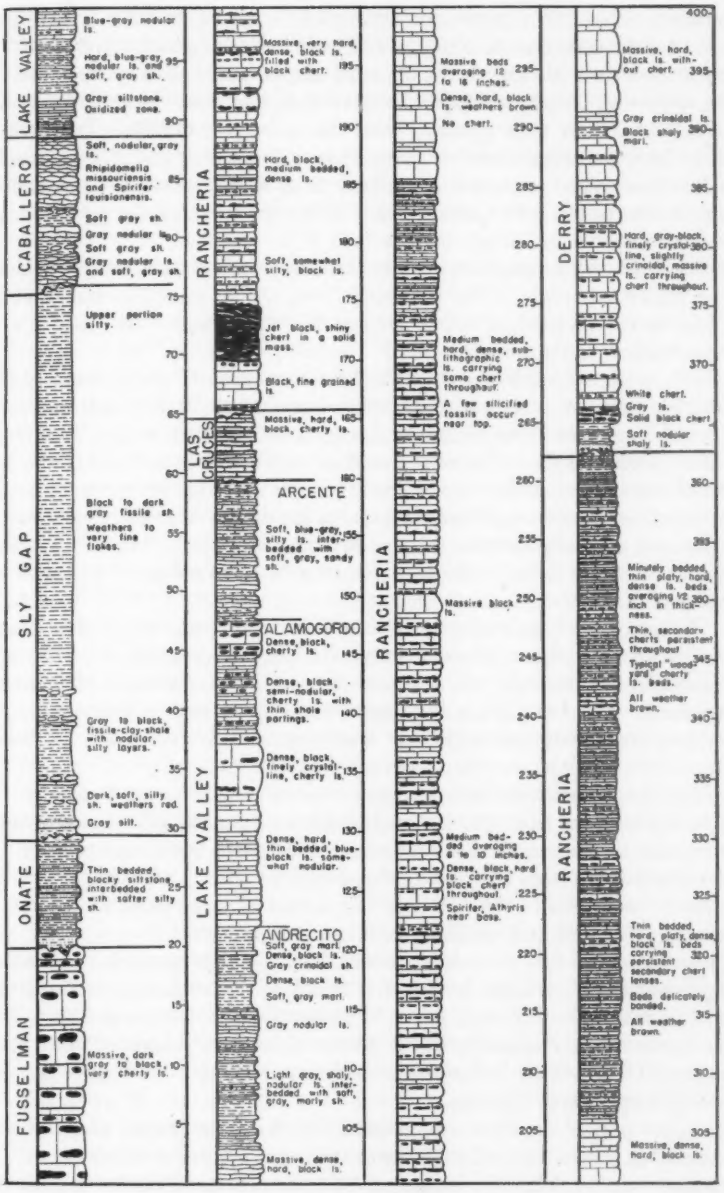
FUSSELMAN
ONATE
SLY GAP
CABALLERO
LAKE VALLEY
RANCHERIA
LAS CRUCES
ARCENTE
ALAMOGORDO
ANDRECITO
LAKE VALLEY
RANCHERIA
DERRY
RANCHERIA
Massive, dark gray to black, very cherty ls.
Thin bedded, blocky siltstone interbedded with softer silty sh.
Dark, soft, silly sh. weathers red.
Gray silt.
Gray to black, fissile-clay-shale with nodular, silty layers.
Black to dark gray fissile sh.
Weathers to very fine flakes.
Upper portion silty.
Soft, nodular, gray ls.
Rhipidomella missouriensis and Spirifer leonisonensis.
Soft gray sh.
Gray nodular ls.
Soft gray sh.
Gray nodular ls. and soft, gray sh.
Blue-gray nodular ls.
Hard, blue-gray, nodular ls. and soft, gray sh.
Gray siltstone. Oxidized zone.
Light gray, shaly, nodular ls. interbedded with soft, gray, marly sh.
Gray nodular ls.
Soft, gray marl.
Dense, black ls.
Gray crinoidal sh.
Dense, black ls.
Soft, gray marl.
Massive, dense, hard, black ls.
Soft, blue-gray, silty ls. interbedded with soft, gray, sandy sh.
Dense, black, cherty ls.
Dense, black, semi-nodular, cherty ls. with thin shale partings.
Dense, black, finely crystalline, cherty ls.
Dense, hard, thin bedded, blue-black ls. somewhat nodular.
Massive, hard, dense, black ls. filled with black chert.
Hard, black, medium bedded, dense ls.
Soft, somewhat silty, black ls.
Jet black, shiny chert in a solid mass.
Black, fine grained ls.
Massive, hard, black, cherty ls.
Massive beds averaging 12 to 16 inches.
Dense, hard, black ls. weathers brown
No chert.
Medium bedded, hard, dense, sub-lithographic ls. carrying some chert throughout.
A few silicified fossils occur near top.
Massive black ls.
Medium bedded averaging 8 to 10 inches.
Dense, black, hard ls. carrying black chert throughout
Spirifer, Athyris near base.
Massive, hard, black ls. without chert.
Gray crinoidal ls.
Black shaly marl.
Hard, gray-black, finely crystalline, slightly crinoidal, massive ls. carrying chert throughout.
White chert.
Gray ls.
Solid black chert.
Soft nodular shaly ls.
Minutely bedded, thin platy, hard, dense ls. beds averaging 1/2 inch in thickness.
Thin, secondary charts persistent throughout
Typical "wood yard" cherty ls. beds.
All weather brown.
Thin bedded, hard, platy, dense, black ls. beds carrying persistent secondary chert lenses.
Beds delicately banded.
All weather brown.
Massive, dense, hard, black ls.

FIGURE 18.—*Bear Canyon section*

SW¼, NW¼, Sec. 30, T 20 S, R 5 E.

Andrecito member. The general appearance of the Andrecito is distinctly different from that of the Caballero because nodular beds are lacking in the Andrecito. The Andrecito weathers to undulating rounded slopes easily distinguished from the blocky-appearing Caballero slopes. Fossils are not common in the Andrecito here, but it is considerably more crinoidal than the underlying Caballero formation and occasionally contains specimens of *Dictyoclostus fernglenensis* and *Athyris lamellosa*. Abundant fenestelloid bryozoans that characterize most exposures of the Andrecito are not present in the Bear Canyon area. A few specimens of *Taonurus caudagalli* were collected.

The black, hard, massive, scarp-forming limestone beds of the Alamogordo member rest on Andrecito strata. This member is very cherty except in the basal part. The Alamogordo member, although only 26 feet thick in this area, makes a conspicuous scarp along the mountain front.

The soft, gray, thin-bedded silts of the Arcente member lie unconformably on the Alamogordo member. The contact is sharp but exhibits little evidence of erosion Absence of Nunn and Tierra Blanca sediments here is the best evidence for recognition of an unconformity. The same conditions exist in the south end of the Sacramento Mountains where Arcente sediments lie on progressively older parts of the Lake Valley formation toward the south end of the range. Apparently the southern shore line was gradually rising so that the Arcente sea overlapped against the slightly eroded lower Lake Valley sediments. No fossils were collected in the Arcente member in Bear Canyon.

A thin northern wedge of the Las Cruces formation is exposed in Bear Canyon. It rests with marked unconformity on the underlying Arcente member. The underlying material is marked by solution channels, and the basal beds of the Las Cruces are oxidized. The Las Cruces consists of remarkably evenbedded, hard, dense black, gray-weathering unfossiliferous limestones. It is recognized on basis of lithologic characteristics and stratigraphic position alone.

The Rancheria formation unconformably overlies the Las Cruces formation. The basal beds consist of hard, black, fine-grained, medium-bedded, detrital limestone relatively free of chert and makes a prominent scarp along the mountain front. The basal scarp-forming beds are overlain by a very unusual, jet-black, massive chert bed about 5 feet thick. An identical bed occurs in some parts of the southern Sacramento Mountain area in a similar stratigraphic position.

Approximately 85 feet of medium-bedded, black, brown-weathering, fossiliferous, cherty limestone follows the chert bed. This part of the Rancheria formation is unusual because of its abundant fossils: *Pennireticulopora* sp., *Rhipidomella* sp., *Dictyoclostus tenuicostatus*, *Linoproductus pileiformis*, *Leiorhynchus carboniferum*, *Spirifer arkansanus*, *Cliothyridina lenticularis*, and *Syringothyris* sp. All these occur in the Moorefield formation of Arkansas.

The upper part of the Rancheria formation in the Bear Canyon area is made up of remarkably thin-bedded, silty limestone beds that weather to a rich brown. The uppermost beds are delicately laminated. The Rancheria formation is unconformably overlain by Pennsylvanian limestone beds. The contact is marked sharply by a basal detrital sandstone and sandy shale.

Ash Canyon section.—Ash Canyon (Fig. 19) is the second large canyon in the San

Andres Mountains that enters the Tularosa Basin north of St. Augustine Pass. Mississippian rocks are well exposed along both canyon walls. Near the mountain front the massive cliffs of Mississippian limestone cap the mountain range. Westward dipping Mississippian rocks plunge beneath the canyon floor a few miles above the mouth of the canyon.

The Caballero formation at the base of the Mississippian section in Ash Canyon lies on the eroded upper surface of the Sly Gap formation. An unusual development of nodular limestone lenses in the soft shales of the Sly Gap formation can easily be mistaken for the nodular beds of the Caballero formation but since both formations are fossiliferous in this area, it is not difficult to recognize the Sly Gap (Devonian) fauna.

A black fissile shale varying from a few inches to several feet in thickness marks the base of the Caballero formation. The black shale is followed by nodular, gray limestones interbedded with soft, gray shales. The percentage of shale increases toward the top. The total thickness of the Caballero formation is 44 feet in this area. Fossils are rare, but a few typical forms were collected.

The Andrecito member of the Lake Valley formation overlies the Caballero formation unconformably. The member has thickened greatly over the short distance between Ash and Bear canyons, reaching its maximum development, approximately 105 feet here. Because it is difficult to pick a contact between the Andrecito and Alamogordo members in this area, probably even more of the section should be placed in the former member than we have put there.

The Andrecito member is thickly developed throughout the central part of the San Andres Range. Excellent exposures can be studied in Ash, San Andres, Andrecito, Lostman, and Deadman canyons. In these areas the Andrecito can be demonstrated to transgressively overlap toward the north onto an unconformable surface. It can also be demonstrated to overlap toward the south, thinning much more rapidly southward than toward the north.

The basal bed of the Andrecito member in the Ash Canyon area is hard, black, fine-grained limestone which forms a distinct scarp over the Caballero slope. The Andrecito member is unusual in this area in that it contains several beds of soft, black to dark-gray, very calcareous, shale between typical black limestone beds. One of these beds is slightly over 6 feet thick, fenestelloid bryozoans occur prolifically in the shale beds along with typical Osage fossils such as *Dictyoclostus fernglenensis*, *Cliothyridina obmaxima*, and *Spirifer vernonensis*.

The remaining part of the Andrecito member consists of medium-bedded, hard, black, sparsely fossiliferous limestone relatively free of chert. The contact between the Andrecito and Alamogordo members is placed tentatively at the first conspicuous chert bed. The beds in the base of the Alamogordo member are lithologically not unlike that of the underlying Andrecito member. *Taonurus caudagalli* occurs occasionally throughout the Andrecito member.

On the north wall of Ash Canyon near the east face of the San Andres Mountains the upper beds of the Andrecito member appear to have been tilted before deposition of the overlying Alamogordo member. This is the only locality in which such relations have been observed.

Slightly more massive, cherty black limestone layers of the Alamogordo member

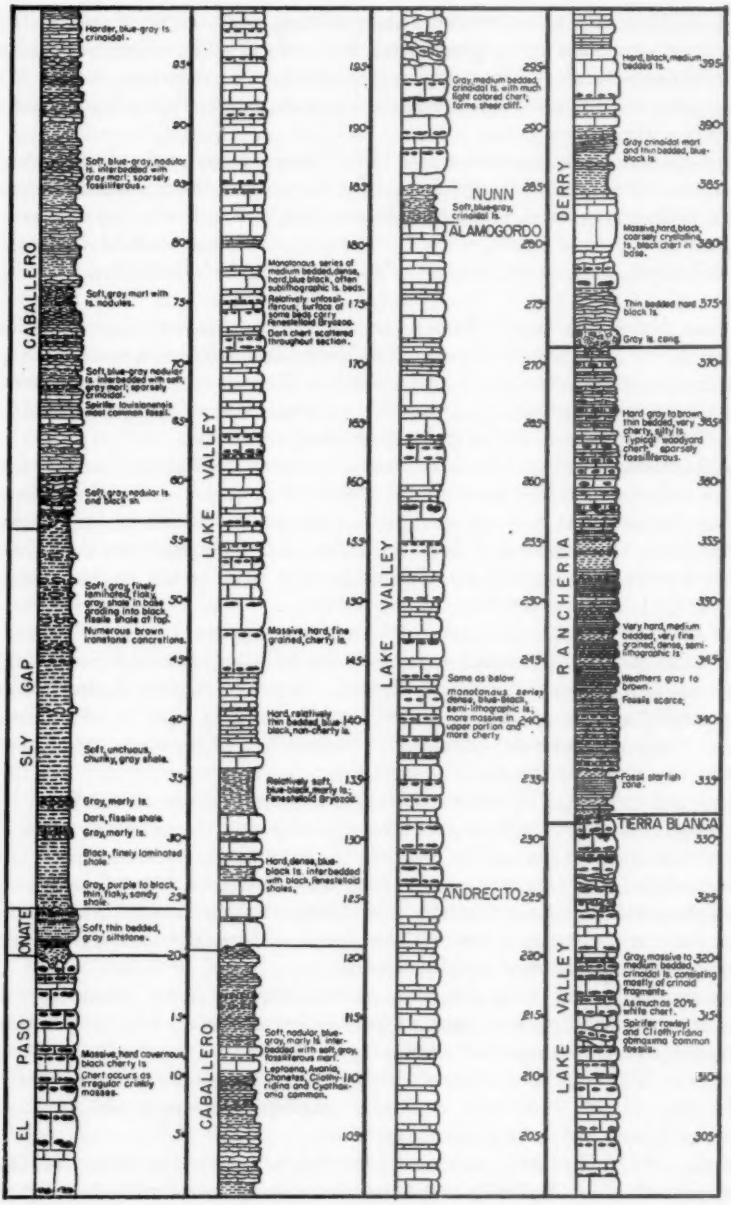

FIGURE 19.—*Ash Canyon section*

NE¼, Sec. 28, T 19 S, R 4 E.

lie above the Andrecito beds. They do not form a conspicuous scarp in Ash Canyon as they do in almost all other areas. They differ also in that the upper part consists of medium-bedded, hard, dense, black limestone beds almost free of chert. No fossils were collected.

The Nunn member is thin in the Ash Canyon area. Approximately 5 feet of very soft, nodular, blue-gray, crinoidal marl carrying thin nodular criquina beds is exposed. It lies between two hard, massive, cliff-forming beds thus making a very prominent break in the cliff. *Steganocrinus*, *Platycrinites*, and *Cactocrinus* were collected from the member.

The Tierra Blanca member rests on the soft marls of the Nunn member with a sharply defined lower surface. The former makes a vertical cliff of medium-bedded, gray to black, crinoidal limestone beds having considerable gray to white chert. Localized very small bioherms occur throughout the section. Fossils other than fragmentary crinoidal remains are rare. Large brachiopods such as *Spirifer rowleyi*, *Cliothyridina obmaxima*, and *Athyris lamellosa* are the most common.

In a few local areas along the north wall of the canyon thin deposits of both Arcente and Dona Ana members are exposed in erosional valleys cut in the Tierra Blanca surface. In a few places the Tierra Blanca member appears to rise up through the Arcente and Dona Ana sediments. The Arcente member, where present, consists of a few feet of evenly bedded, soft, gray, silty limestones, and the Dona Ana mainly of red, iron-stained, and white chert with minor amounts of gray, crinoidal limestone. Over most of the area the Rancheria formation lies directly on the Tierra Blanca surface.

No Las Cruces strata are exposed in the Ash Canyon area. The Rancheria formation rests unconformably on an eroded Lake Valley surface with a distinct contact. The considerable relief of the underlying surface is plainly visible within very short distances along the outcrop. Thin red, oxidized, silty sandstone beds occur in a few local depressions on this surface.

The Rancheria formation is 39 feet thick and of very thin-bedded, markedly even-bedded, hard, gray, limestone beds that weather to a rich brown. Thin, "crinkly" chert beds occur throughout the formation. Fossils are fairly abundant but difficult to collect. One most unusual bed has many specimens of starfish. *Leiorhynchus carboniferum* is the commonest fossil.

The Rancheria formation is unconformably overlain by beds of Pennsylvanian age. A gray limestone conglomerate marks the contact.

San Andres Canyon section.—San Andres Canyon (Fig. 20) is the third large canyon that enters the Tularosa Basin north of St. Augustine Pass in the San Andres Mountains. The canyon mouth is located about 6 miles northwest of San Andres Peak.

Pre-Cambrian rocks are exposed along the east base of the mountains in San Andres Canyon. Ordovician and Devonian sediments lie above the pre-Cambrian and below the Mississippian escarpment. Steep cliffs of Mississippian limestone cap the face of the range in this area. Pennsylvanian sediments occur mainly on the secondary escarpments to the west.

The Caballero formation lies at the base of the Mississippian section in San Andres

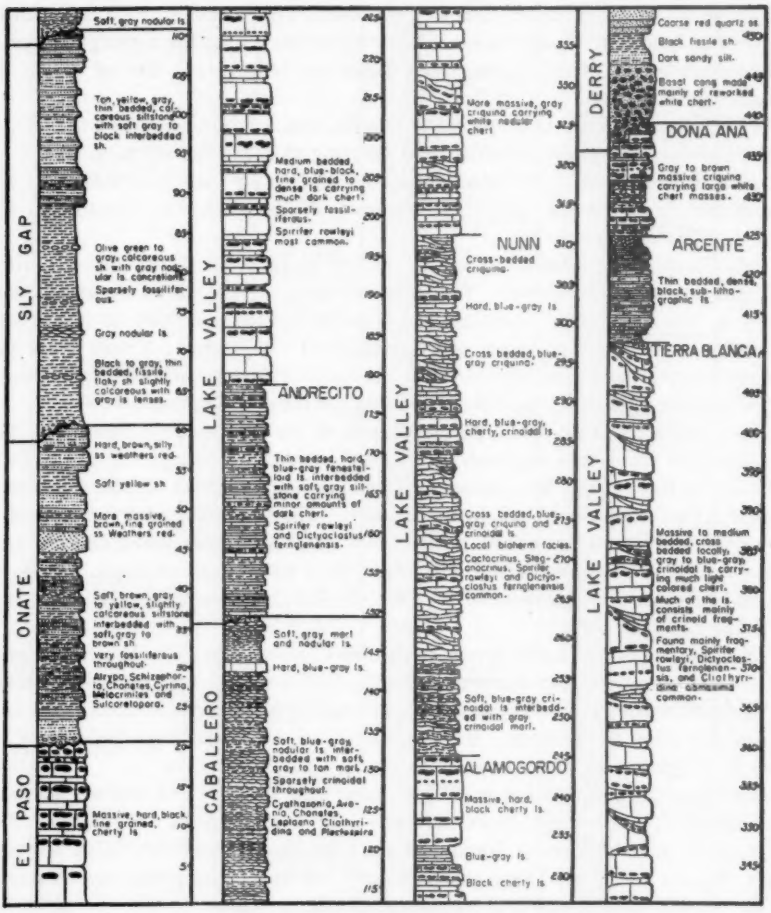
EL PASO
ONATE
SLY GAP
CABALLERO
LAKE VALLEY
ANDRECITO
LAKE VALLEY
NUNN
ALAMOGORDO
LAKE VALLEY
DERRY
DONA ANA
ARCENTE
TIERRA BLANCA
Soft, gray nodular ls.
Tan, yellow, gray, thin bedded, calc. calcareous siltstone with soft gray to black interbedded sh.
Olive green to gray, calcareous sh with gray nodular ls. concretions. Sparsely fossiliferous.
Gray nodular ls.
Black to gray, thin bedded, fissile, flaky sh slightly calcareous with gray ls lenses.
Hard, brown, silty ss weathers red.
Soft yellow sh
Mora massive, brown, fine grained ss. Weathers red.
Soft, brown, gray to yellow, slightly calcareous siltstone interbedded with soft, gray to brown sh. Very fossiliferous throughout. Alveyna, Schizophoria, Chonetes, Cyrtina, Melocrinites and Sulcoretopora.
Massive, hard, black, fine grained, cherty ls.
Medium bedded, hard, blue-black, fine grained to dense ls carrying much dark chert. Sparsely fossiliferous. Spirifer rowleyi most common.
Thin bedded, hard, blue-gray fenestella-oid ls. interbedded with soft, gray siltstone carrying minor amounts of dark chert. Spirifer rowleyi and Dictyoclostus ferreglenensis.
Soft, gray marl and nodular ls.
Hard, blue-gray ls.
Soft, blue-gray, nodular ls. interbedded with soft, gray to tan marl. Sparsely crinoidal throughout. Cyathaxonia, Arenia, Chonetes, Lepidena, Cleithrinidina and Pachyasaira
Mora massive, gray crinoina carrying white nodular chert
Cross-bedded crinoina.
Hard, blue-gray ls
Cross bedded, blue-gray crinoina.
Hard, blue-gray, cherty, crinoidal ls.
Cross bedded, blue-gray crinoina and crinoidal ls. Local bioherm facies. Cactocrinus, Stegnocrinus, Spirifer rowleyi and Dictyoclostus ferreglenensis common.
Soft, blue-gray crinoidal ls interbedded with gray crinoidal marl.
Massive, hard, black cherty ls.
Blue-gray ls.
Black cherty ls.
Coarse red quartz ss
Black fissile sh.
Dark sandy silt.
Basal cong made mainly of reworked white chert.
Gray to brown massive crinoina carrying large white chert masses.
Thin bedded, dense, black, sub-lithographic ls
Massive to medium bedded, cross bedded locally, gray to blue-gray crinoidal ls carrying much light colored chert. Much of the ls. consists mainly of crinoid fragments. Fauna mainly fragmentary, Spirifer rowleyi, Dictyoclostus ferreglenen-sis, and Cleithyridina obmamma common.

FIGURE 20.—*San Andres Canyon section*

NW¼, Sec. 17, T 18 S, R 4 E.

Canyon, resting unconformably on the Sly Gap formation of Devonian age. The upper beds of the Sly Gap formation are hard, massive, scarp-forming, brown-weathering, silty, very fossiliferous dolomite. Approximately 38 feet of gray, nodular beds of the Caballero formation contrast with the hard, brown beds of the Devonian. The formation is not markedly fossiliferous in San Andres Canyon, but a few typical Caballero species, *Avonia boonensis*, *Dictyoclostus chouteauensis*, *Brachythyris peculiaris* and *Spirifer louisianensis* were found.

The Andrecito member of the Lake Valley formation lies unconformably on the Caballero. It consists of 28 feet of very thin-bedded, dark-gray, slightly cherty limestone, interbedded with soft, dark, blue-gray, shales and weathers to a rubbly

slope not unlike that of the underlying Caballero formation. The Andrecito member, markedly different lithologically from the Caballero, is evenly bedded and has no tendency to become nodular. The Andrecito member is quite crinoidal and carries large, typically Osage brachiopods such as *Spirifer rowleyi* and *Dictyoclostus fernglensis*. Fenestelloid bryozoans occur abundantly in the shales of the lower part of the member.

The rapid changes in thickness of the Andrecito member indicate that an unconformity may exist between these Kinderhook and Osage strata.

The Alamogordo member, sharply defined in San Andres Canyon, consists of 67 feet of hard, massive, black cherty limestone which overhangs the softer beds of the underlying Andrecito member. The Alamogordo member is abnormally thick in San Andres Canyon and contains a soft, thin-bedded, limestone bed a few feet below the top.

The Nunn member is variable in San Andres Canyon because a large bioherm rises through it near the upper end of the canyon. In that area the Nunn member consists almost entirely of coarse criquina. Soft, very fossiliferous, blue-gray marls are interbedded with the criquina beds in the lagoonal facies farther east along the canyon wall. An excellent crinoid fauna was collected from these Nunn marls along the north canyon wall. The fauna includes: *Rhodocrinites barrisi*, *Actinocrinites* cf. *A. rubra*, *Steganocrinus pentagonus*, *Cactocrinus* sp., *Amphoracrinus divergens* and *Platycrinites halli*.

The Tierra Blanca member of massive gray to black crinoidal limestone with considerable white chert is excellently developed in San Andres Canyon and makes a sheer cliff nearly 100 feet high near the mouth of the canyon. Near the bioherm at the canyon head, the Tierra Blanca member appears to grade imperceptibly into the criquina of the underlying Nunn member. The former consists of medium-bedded to massive, gray to black, very crinoidal limestone which carries considerable amounts of nodular white chert.

The Arcente member, 14 feet thick, rests unconformably on the Tierra Blanca member, with a sharply defined boundary. Considerable relief and evidence of solution are apparent on the Tierra Blanca surface. Marked changes in thickness are also discernible within very short distances. Rounded, abraded, apparently reworked, fossils occur in the basal few inches of the Arcente member. Along parts of the north canyon wall, the boundary between the Arcente and Dona Ana appears to be unconformable, and at one place the Arcente appears to have been overlapped by the Dona Ana. This is the only area where unconformable relations were found between the Dona Ana and Arcente members.

The Dona Ana member consists mainly of chert residue beneath the Pennsylvanian strata. Cavernous, oxidized, gray limestone criquina, filled with large masses of white chert, occurs in a few areas. Because it is harder than the underlying Arcente member, low scarps are formed. The Dona Ana is overlain by a Pennsylvanian basal conglomerate which is lithologically inconsistent along the contact. The chert concentrations are not always present and brown, silty Pennsylvanian limestones rest directly on the Dona Ana. In a few places the Dona Ana has been removed, and the Pennsylvanian strata rest directly on the Arcente beds.

Andrecito Canyon section.—Andrecito Canyon is a moderately small canyon 2

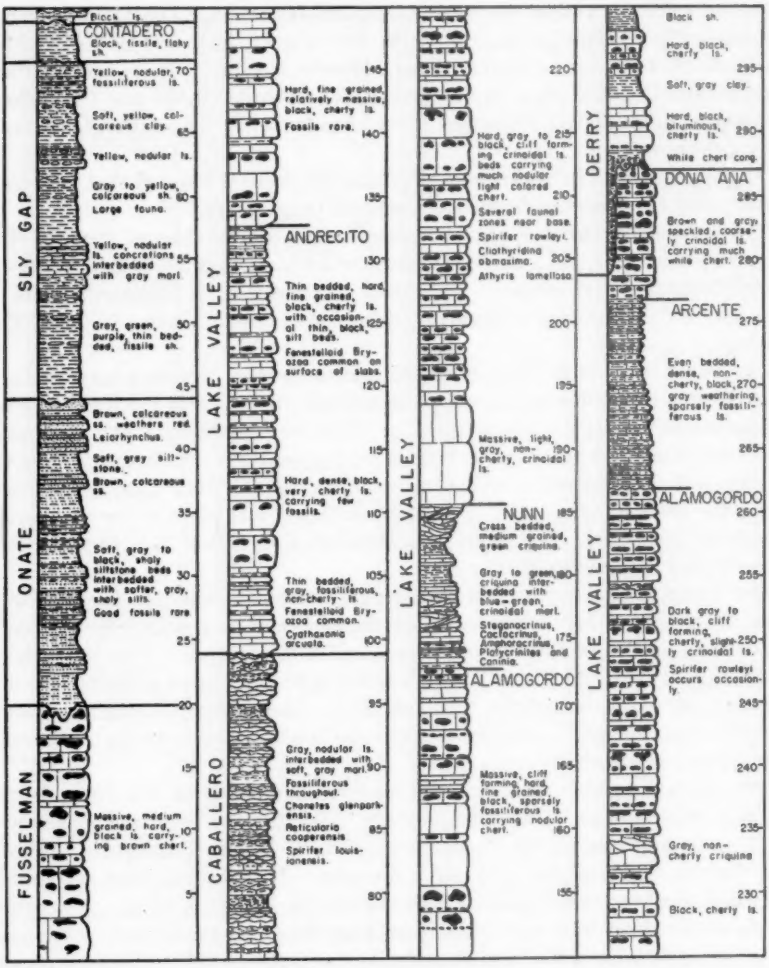
FUSSELMAN
ONATE
SLY GAP
CONTADERO
Black, fissile, fishy sh.
Yellow, nodular, fossiliferous ls.
Soft, yellow, calcareous clay.
Yellow, nodular ls.
Gray to yellow, calcareous sh. Large fauna.
Yellow, nodular ls. concretions interbedded with gray marl.
Gray, green, purple, thin bedded, fissile sh.
Brown, calcareous ss. weathers red. Leiorhynchus.
Soft, gray siltstone.
Brown, calcareous ss.
Soft, gray to black, shaly siltstone beds interbedded with softer, gray, shaly silts. Good fossils rare
Massive, medium grained, hard, black to carrying brown chert.
CABALLERO
LAKE VALLEY
Hard, fine grained, relatively massive, black, cherty ls.
Fossils rare.
ANDRECITO
Thin bedded, hard, fine grained, black, cherty ls. with occasional thin, black silt beds.
Fenestelloid Bryozoa common on surface of slabs.
Hard, dense, black, very cherty ls. carrying few fossils.
Thin bedded, gray, fossiliferous, non-cherty ls.
Fenestelloid Bryozoa common.
Cyathaxonia arcuata.
Gray, nodular ls. interbedded with soft, gray marl.
Fossiliferous throughout.
Chonetes glenparkensis.
Reticularia cooperensis
Spirifer louisianensis.
LAKE VALLEY
Hard, gray to black, cliff forming crinoidal ls. beds carrying much nodular light colored chert.
Several faunal zones near base.
Spirifer rowleyi.
Cliothyridina obmasima.
Athyris lamellosa
Massive, light gray, non-cherty, crinoidal ls.
NUNN
Cross bedded, medium grained, green crinoina.
Gray to green crinoina interbedded with blue-green, crinoidal marl.
Steganocrinus, Cactocrinus, Amphoracrinus, Platycrinites and Cannia.
ALAMOGORDO
Massive, cliff forming, hard, fine grained black, sparsely fossiliferous ls. carrying nodular chert.
DERRY
LAKE VALLEY
Black sh.
Hard, black, cherty ls.
Soft, gray clay.
Hard, black, bituminous, cherty ls.
White chert cong.
DONA ANA
Brown and gray speckled, coarsely crinoidal ls. carrying much white chert.
ARCENTE
Even bedded, dense, non-cherty, black, gray weathering, sparsely fossiliferous ls.
ALAMOGORDO
Dark gray to black, cliff forming, cherty, slightly crinoidal ls.
Spirifer rowleyi occurs occasionally.
Gray, non-cherty crinoina
Black, cherty ls.

FIGURE 21.—*Andrecito Canyon section*

NW¼, NW¼, Sec. 8, T 18 S, R 4 E.

miles north of San Andres Canyon, approximately mid-way between San Andres and Mayberry Canyons. The measured section (Fig. 21) lies on the south canyon wall near the mouth.

The Caballero formation lies at the base of the Mississippian section on the fissile black shale of the Contadero formation (Stevenson, 1945, p. 239). The soft, nodular, gray limestone beds of the Caballero overhang the soft Contadero sediments and make a pronounced scarp. The Caballero formation is lithologically typical but

becomes slightly more shaly toward the top. It is thinner in this area. Considerable parts of the harder, less shaly, basal beds are missing and it appears to overlap against the irregular underlying surface.

The Andrecito member, resting unconformably on the Caballero, consists in the base of thin-bedded, gray limestone without chert, and in the upper part of medium-bedded, black, slightly cherty limestone. Lithologically, the upper part of the Andrecito is not markedly unlike that of the overlying Alamogordo member. A thin-bedded, soft, gray limestone zone lies at the top of the member just beneath the Alamogordo scarp.

The Alamogordo member consists of massive, hard, black, scarp-forming, cherty limestone that makes a distinct scarp along the mountain front. One soft, thinly bedded, gray limestone zone a few feet below the top may represent the same zone as the one so well developed in San Andres Canyon.

The Nunn member is thin and poorly developed in Andrecito Canyon. It consists of approximately 12 feet of soft, thin-bedded, blue-gray crinoidal limestone interbedded with two soft, crinoidal marl zones. *Steganocrinus pentagonus* and *Spirifer rowleyi* were collected from the marl beds.

The Tierra Blanca member, the most conspicuous part of the Mississippian sequence in this area, forms a sheer massive cliff 75 feet high. The base is unusually massive, light-gray, crinoidal, noncherty limestone. The remainder is typically medium-bedded, gray criquina having considerable white chert.

The Arcente member rests unconformably on the Tierra Blanca. Evidence of unconformity is not as strong here as in San Andres Canyon. The Arcente consists of relatively thin-bedded, soft, gray, dense, silty limestones. Because it is soft it makes a retreating portion of the mountain slope.

Slightly over 12 feet of Dona Ana, massive weathered, oxidized, gray criquina filled with masses of weathered, white chert, are exposed in the canyon. In a few places the Pennsylvanian cuts down through the Dona Ana and into the Arcente member. A conglomerate of reworked chert marks the base of the Pennsylvanian over most of the area. Rapid changes in thickness of the chert conglomerate are seen along the mountain front.

Deadman Canyon Section.—Deadman Canyon (Fig. 22) in the central part of the San Andres Mountains approximately 8 miles north of San Andres Canyon is a large, well-developed channel which drains a large part of the back slope of the San Andres Mountains. It can be reached by road through the Lucero Ranch.

The Caballero formation lies at the base of the Mississippian section and is unconformable on the Contadero (Devonian) formation. The basal beds of the Caballero formation overhang the soft Cantadero sediments, making a definite escarpment along the canyon wall. The basal beds of the Caballero formation are gray, calcareous siltstone with considerable material reworked from the underlying Contadero formation. A soft, gray, silty shale overlies the basal siltstone below typical, nodular, gray Caballero sediment.

The Andrecito member, excellently developed in the Deadman Canyon area, rests unconformably on the Caballero formation and can be differentiated easily from the Caballero because basal beds of the former are not nodular. It consists of ap-

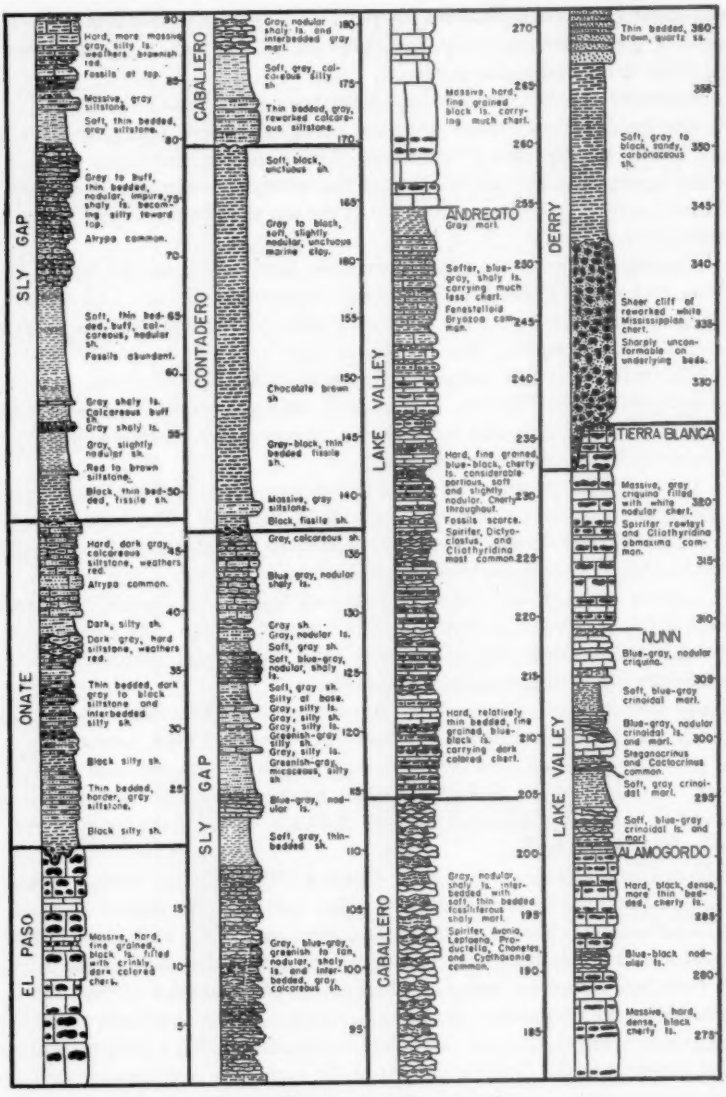
EL PASO
ONATE
SLY GAP
CABALLERO
SLY GAP
CONTADERO
CABALLERO
LAKE VALLEY
ANDRECITO
Gray marl.
LAKE VALLEY
DERRY
TIERRA BLANCA
NUNN
ALAMOGORDO
Massive, hard, fine grained, black ls. filled with crinkly dark colored chert.
Thin bedded, harder, gray siltstone.
Dark, silty sh.
Dark gray, hard siltstone, weathers red.
Thin bedded, dark gray to black siltstone and interbedded silty sh.
Black silty sh.
Hard, dark gray, calcareous siltstone, weathers red.
Atrypa common.
Massive, gray siltstone.
Soft, thin bedded, gray siltstone.
Grey to buff, thin bedded, nodular, impure, shaly ls. becoming silty toward top.
Atrypa common.
Soft, thin bedded, buff, calcareous, nodular sh.
Fossils abundant.
Gray shaly ls.
Calcareous buff sh.
Gray shaly ls.
Gray, slightly nodular sh.
Red to brown siltstone.
Black, thin bedded, fissile sh.
Hard, more massive gray, silty ls. weathers brownish red.
Fossils at top.
Gray, nodular shaly ls. and interbedded gray marl.
Soft, gray, calcareous silty sh.
Thin bedded, gray, reworked calcareous siltstone.
Soft, black, unctuous sh.
Gray to black, soft, slightly nodular, unctuous marine clay.
Chocolate brown sh
Gray-black, thin bedded fissile sh.
Massive, gray siltstone.
Black, fissile sh.
Gray, calcareous sh.
Blue gray, nodular shaly ls.
Gray sh.
Gray, nodular ls.
Soft, gray sh.
Soft, blue-gray, nodular, shaly ls.
Soft, gray sh.
Silty at base.
Gray, silty ls.
Gray, silty sh.
Gray, silty ls.
Greenish-gray silty sh.
Gray, silty ls.
Greenish-gray, mcsseous, silty sh
Blue-gray, nodular ls.
Soft, gray, thin-bedded sh.
Gray, blue-gray, greenish to tan, nodular, shaly ls. and interbedded, gray, calcareous sh.
Massive, hard, fine grained, black ls. carrying much chert.
Softer, blue-gray, shaly ls. carrying much less chert.
Fenestellid Bryozoa common.
Hard, fine grained, blue-black, cherty ls. considerable portions, soft and slightly nodular. Cherty throughout.
Fossils scarce. Spirifer, Dictyoclostus, and Cliothyridina most common.
Hard, relatively thin bedded, fine grained, blue-black ls. carrying dark colored chert.
Gray, nodular, shaly ls. interbedded with soft, thin bedded fossiliferous shaly marl.
Spirifer, Avonia, Leptaena, Productella, Chonetes, and Cyrtinaxonia common.
Thin bedded, brown, quartz ss.
Soft, gray to black, sandy, carbonaceous sh.
Sheer cliff of reworked white Mississippian chert.
Sharply unconformable on underlying beds.
Massive, gray crinoid filled with white nodular chert.
Spiriter rowleyi and Cliothyridina obmaxima common.
Blue-gray, nodular crinoid.
Soft, blue-gray crinoidal marl.
Blue-gray, nodular crinoidal ls. and marl.
Steganocrinus and Cactocrinus common.
Soft, gray crinoidal marl.
Soft, blue-gray crinoidal ls. and marl.
Hard, black, dense, more thin bedded, cherty ls.
Blue-black nodular ls.
Massive, hard, dense, black cherty ls.

FIGURE 22.—*Deadman Canyon section*

SW¼, SE¼, Sec. 12, T 17 S, R 3 E.

proximately 50 feet of thin-bedded, dark-gray to black cherty limestone, nodular and slightly crinoidal in the medial part but lacking the interbedded soft shales that characterize nodular Caballero beds. The upper part is soft and silty, and a soft bed of silty shale lies immediately below the contact with the overlying Alamogordo

member. Fenestelloid bryozoans are abundant in the beds immediately below the Alamogordo member.

The Alamogordo member, typically black, hard, massive, fine-grained, sparsely fossiliferous, cherty limestone, makes a prominent scarp along the mountain front. A soft blue-black, nodular limestone bed occurs a few feet below the top in this canyon as in Andrecito and San Andres canyons.

The Nunn member, 18 feet thick, is thinly but typically developed. It consists of soft, nodular, blue-gray, criquina beds, interbedded with highly fossiliferous, blue-gray marls. *Steganocrinus pentagonus*, *Physetocrinus copei*, *Amphoracrinus divergens*, *Platycrinites pocilliformis*, and *Platycrinites* cf. *P. burlingtonensis* have been identified from the marl beds.

The Tierra Blanca member in this area is 17 feet of massive, gray, cherty criquina, having been largely removed by pre-Pennsylvanian erosion. Both Arcente and Dona Ana members have been removed by pre-Pennsylvanian erosion. The basal conglomerates of the Pennsylvanian contain rounded reworked Mississippian cherts and are resistant to erosion making conspicuous scarps. These cherts rest on a weathered surface and in many places lie in solution channels that penetrate the Tierra Blanca.

Lostman Canyon section.—Lostman Canyon, approximately 1½ miles north of Deadman Canyon, is one of the minor drainage channels in the San Andres Mountains and is accessible by road from Deadman Canyon. The section measured in Lostman Canyon (Fig. 23) is on the south wall near the head of the canyon.

The Caballero formation at the base of the Mississippian section, lies unconformably on the soft shales of the Contadero formation (Devonian). The basal Caballero beds make a distinct scarp above the Contadero shale along the mountain front. The Caballero, exceptionally well developed in this canyon, thickened by addition of strata at its base reaches a thickness of approximately 48 feet. The harder, less shaly, slightly nodular beds that characterize the basal part of the Caballero formation in the Sacramento Mountains also occur at the base of the Lostman Canyon Section. The upper layers have their normal soft, shaly character.

The Andrecito member of the Lake Valley formation overlies the Caballero formation unconformably. The contact is easily discernible because the basal Andrecito beds are harder than the upper beds of the Caballero and consequently usually overhang the Caballero sediments with a low scarp. The Andrecito consists of moderately thin-bedded, blue-black, fine-grained limestone with black chert in the upper part. The very thin beds covered with fenestelloid bryozoans that generally occur at the base of the Andrecito member are missing in this area.

The Alamogordo member, overlying the Andrecito with a conspicuous scarp, is massive, black, fine-grained, sparsely fossiliferous, cherty limestone, 64 feet thick in Lostman Canyon.

The Nunn member is thin here but being soft it weathers rapidly and forms a low shelf along the top of the Alamogordo making a distinct break in the massive cliff of Mississippian rocks. It is approximately 12 feet thick and consists of typical blue-gray criquina and crinoidal marls. *Steganocrinus*, *Cactocrinus*, and *Platycrinites* have been identified from the member.

The Tierra Blanca member is spectacularly developed in Lostman Canyon where

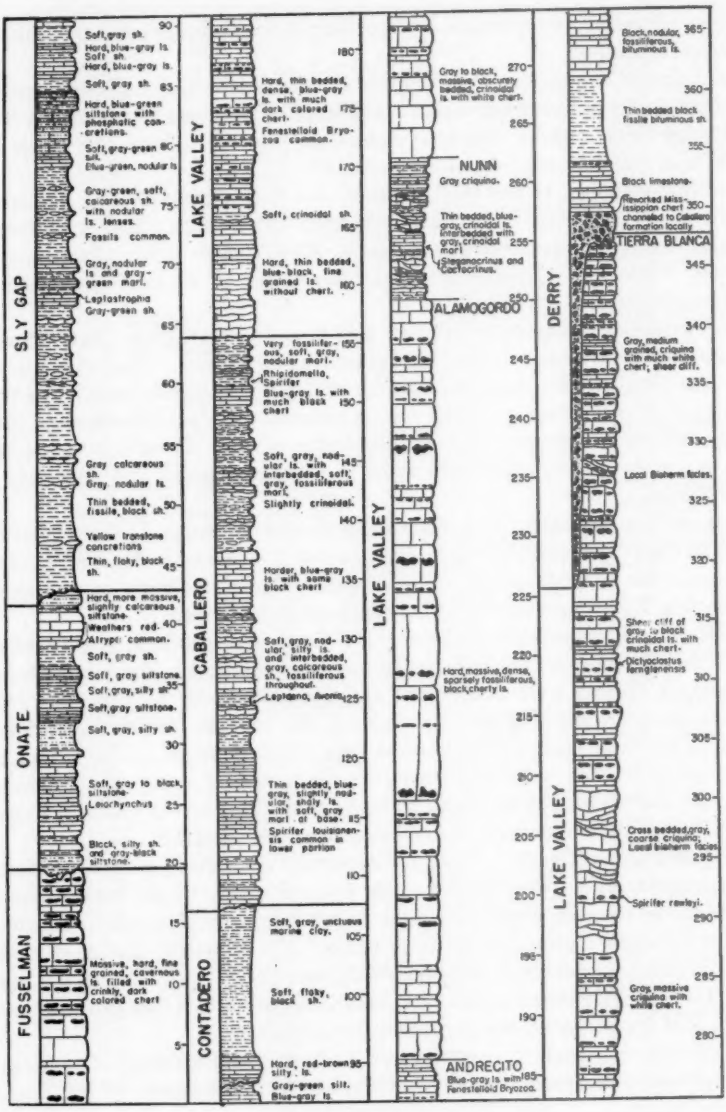
SLY GAP
ONATE
FUSSELMAN
LAKE VALLEY
CABALLERO
CONTADERO
LAKE VALLEY
DERRY
LAKE VALLEY
NUNN
ALAMOGORDO
ANDRECITO
TIERRA BLANCA
Soft, gray sh.
Hard, blue-gray ls.
Soft sh.
Hard, blue-gray ls.
Soft, gray sh.
Hard, blue-green siltstone with phosphatic concretions.
Soft, gray-green silt.
Blue-green, nodular ls
Gray-green, soft, calcareous sh. with nodular ls. lenses.
Fossils common.
Gray, nodular ls and gray-green marl.
Leptostrophia
Gray-green sh.
Gray calcareous sh.
Gray nodular ls.
Thin bedded, fissile, black sh.
Yellow ironstone concretions
Thin, flaky, black sh.
Hard, more massive, slightly calcareous siltstone.
Weathers red.
Atrypa common.
Soft, gray sh.
Soft, gray siltstone
Soft, gray, silty sh.
Soft, gray siltstone.
Soft, gray, silty sh.
Soft, gray to black, siltstone
Leiorhynchus
Black, silty sh. and gray-black siltstone.
Massive, hard, fine grained, cavernous ls. filled with crinkly, dark colored chert
Hard, thin bedded, dense, blue-gray ls. with much dark colored chert.
Fenestelloid Bryozoa common.
Soft, crinoidal sh.
Hard, thin bedded, blue-black, fine grained ls. without chert.
Very fossiliferous, soft, gray, nodular marl.
Rhipidomella, Spirifer
Blue-gray ls. with much black chert
Soft, gray, nodular ls. with interbedded, soft, gray, fossiliferous marl.
Slightly crinoidal.
Harder, blue-gray ls. with some black chert
Soft, gray, nodular, silty ls. and interbedded, gray, calcareous sh., fossiliferous throughout.
Leptaena, Avonia
Thin bedded, blue-gray, slightly nodular, shaly ls. with soft, gray marl at base.
Spirifer louisianensis common in lower portion
Soft, gray, unctuous marine clay.
Soft, flaky, black sh.
Hard, red-brown silty ls.
Gray-green silt.
Blue-gray ls.
Gray to black, massive, obscurely bedded, crinoidal ls. with white chert.
Gray crinoina.
Thin bedded, blue-gray, crinoidal ls. interbedded with gray, crinoidal marl
Stegnacrinus and Cactocrinus.
Hard, massive, dense, sparsely fossiliferous, black, cherty ls.
Blue-gray ls. with Fenestelloid Bryozoa.
Black, nodular, fossiliferous, bituminous ls.
Thin bedded black fissile bituminous sh.
Black limestone.
Reworked Mississippian chert channeled to Caballero formation locally.
Gray, medium grained, crinoina with much white chert, sheer cliff.
Local Bioherm facies.
Sheer cliff of gray to black crinoidal ls. with much chert.
Dictyoclostus farnglenensis
Cross bedded, gray, coarse crinoina; Local bioherm facies
Spirifer rowleyi.
Gray, massive crinoina with white chert.

FIGURE 23.—*Lostman Canyon section*

SE¼, SE¼, Sec. 36, T 16 S, R 3 E.

it forms a sheer vertical cliff slightly over 85 feet high. It consists of hard, gray to black, massive crinoidal limestone that contains considerable amounts of gray nodular chert. The lower part is massive, obscurely bedded limestone made up

almost entirely of crinoid fragments. Fossils are present throughout the Tierra Blanca member but are difficult to collect. Large brachiopods are common.

If either Arcente or Dona Ana sediments were ever present in Lostman Canyon they were removed by pre-Pennsylvanian erosion. The Tierra Blanca member is overlain by Pennsylvanian rocks that contain considerable reworked Mississippian chert just above the contact. These cherts lie on a very irregular surface, and midway between Lostman and Deadman canyons a channel cuts through both Tierra Blanca and Nunn members and into the Alamogordo member. These Pennsylvanian cherty conglomerates make conspicuous scarps along the mountain front.

Rich Rim section.—Rich Rim is a conspicuous eastward-projecting salient of the San Andres Mountain front lying about 3½ miles north of Deadman Canyon. Mississippian rocks cap this conspicuous escarpment and dip steeply west toward the Jornada Del Muerto. The section measured (Fig. 24) lies along the southeast side of the escarpment.

Caballero sediments are absent in this area. The Contadero formation (Devonian) thickens conspicuously and probably was left as an erosional high before Mississippian sediments were deposited. Caballero strata overlap transgressively to the north, the formation being absent locally as at Rich Rim. The Andrecito member of the Lake Valley formation is unusually thick and here the added beds lie at the base of the member. Caballero sediments may have been removed before Andrecito sediments were laid down. Caballero sediments have not been observed north of this area in the San Andres Mountains, but there is a considerable gap between the Rich Rim area and our next studied section at Rhodes Canyon. Thin sequences of the Caballero formation may eventually be found between these canyons.

The Andrecito member of the Lake Valley formation rests unconformably on the Contadero formation. A black shale containing phosphatic concretions and fish teeth lies at the base of the section and is overlain by hard, massive, scarp-forming, dark-gray, fine-grained limestone beds with a few chert nodules in the upper portion. Gray marl, nodular limestone, and gray calcareous sandstone overlie the massive beds before typical Andrecito sediments are seen. As the Andrecito member is unusually thick in this area, it is assumed that these sediments represent an older part of the Andrecito than any seen in other parts of the San Andres Mountains. The upper part of the Andrecito member is typically medium-bedded, hard, blue-black, sparsely fossiliferous, very cherty limestone. The Andrecito is 82 feet thick here, a maximum for the San Andres Mountains.

The Alamogordo member, of typically black, hard, massive, fine-grained, very cherty limestone, can be differentiated from the underlying Andrecito member only because the former is the more massive. Black and white, concentrically-banded chert nodules often common in the Alamogordo member are present here.

The Nunn member, 33 feet thick, consists of three distinct units. The lower beds are typically blue-gray, soft, crinoidal marl. A conspicuous ledge of coarsely-grained, criquina bed occupies the central part of the member. The top beds are a mixture of blue-gray criquinas interbedded with soft crinoidal marls.

The Tierra Blanca member forms a vertical, gray cliff approximately 60 feet high composed of medium-bedded to massive, gray crinoidal limestone beds that carry

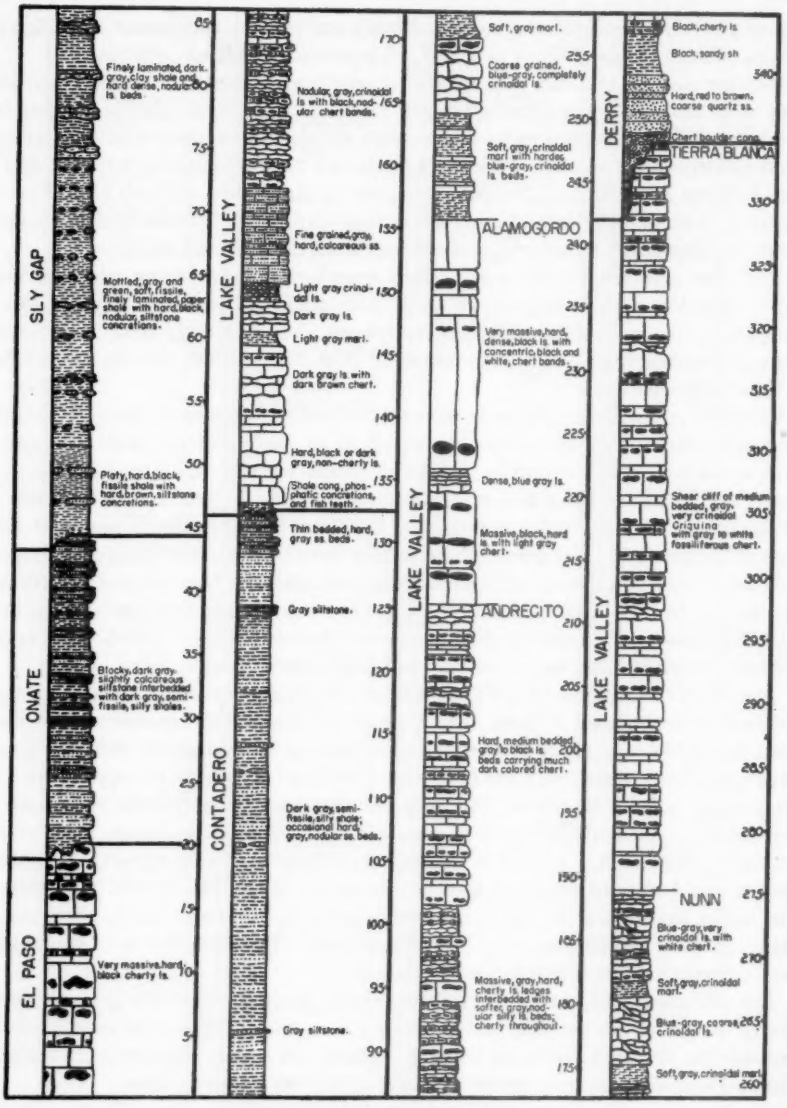
EL PASO
ONATE
SLY GAP
CONTADERO
LAKE VALLEY
LAKE VALLEY
LAKE VALLEY
DERRY
TIERRA BLANCA
ALAMOGORDO
ANDRECITO
NUNN
Very massive, hard, black cherty ls.
Blocky, dark gray, slightly calcareous siltstone interbedded with dark gray, semi-fissile, silty shales.
Platy, hard, black, fissile shale with hard, brown, siltstone concretions.
Mottled, gray and green, soft, fissile, finely laminated, paper shale with hard, black, nodular, siltstone concretions.
Finely laminated, dark gray, clay shale and hard dense, nodular ls. beds
Gray siltstone.
Dark gray, semi-fissile, silty shale; occasional hard, gray, nodular ss. beds.
Gray siltstone.
Thin bedded, hard, gray ss. beds.
Shale cong., phosphatic concretions, and fish teeth.
Hard, black or dark gray, non-cherty ls.
Dark gray ls. with dark brown chert.
Light gray marl.
Dark gray ls.
Light gray crinoidal ls.
Fine grained, gray, hard, calcareous ss.
Nodular, gray, crinoidal ls with black, nodular chert bands.
Soft, gray marl.
Coarse grained, blue-gray, completely crinoidal ls.
Soft, gray, crinoidal marl with hard, blue-gray, crinoidal ls beds.
Very massive, hard, dense, black ls. with concentric, black and white, chert bands.
Dense, blue gray ls.
Massive, black, hard ls. with light gray chert.
Hard, medium bedded, gray to black ls. beds carrying much dark colored chert.
Massive, gray, hard, cherty ls. ledges interbedded with softer, gray, nodular silty ls. beds, cherty throughout.
Black, cherty ls.
Black, sandy sh
Hard, red to brown, coarse quartz ss.
Chert boulder conc.
Shear cliff of medium bedded, gray, very crinoidal Grayina with gray to white fossiliferous chert.
Blue-gray, very crinoidal ls. with white chert.
Soft, gray, crinoidal marl.
Blue-gray, coarse, crinoidal ls.
Soft, gray, crinoidal marl.

FIGURE 24.—*Rich Rim section*

NE¼, SE¼, Sec. 19, T 16 S, R 4 E.

considerable portions of gray nodular chert. Arcente and Dona Ana sediments are not present. Pennsylvanian conglomerates of reworked Mississippian cherts lie in contact with the Tierra Blanca member. Her the beds of chert conglomerate do not form massive cliffs such as are exposed in Lostman Canyon.

Rhodes Canyon section.—Rhodes Canyon is one of the major drainage channels entering the Tularosa Basin from the San Andres Mountains. New Mexico State Highway 52 runs up Rhodes Canyon. Mississippian strata cross the canyon floor

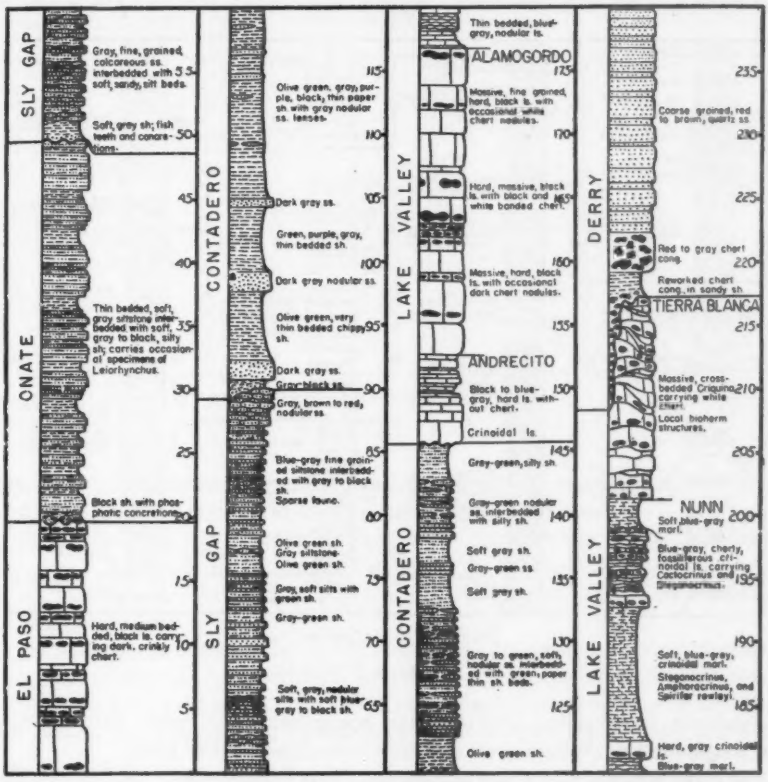
EL PASO
ONATE
SLY GAP
CONTADERO
SLY GAP
CONTADERO
LAKE VALLEY
LAKE VALLEY
DERRY
Gray, fine, grained, calcareous ss. interbedded with soft, sandy, silt beds.
Soft, grey sh; fish teeth and concretions.
Thin bedded, soft, gray siltstone interbedded with soft, gray to black, silty sh; carries occasional specimens of Leiorhynchus.
Black sh. with phosphatic concretions.
Hard, medium bedded, black ls. carrying dark, crinkly chert.
Olive green, gray, purple, black, thin paper sh. with gray nodular ss. lenses.
Dark gray ss.
Green, purple, gray, thin bedded sh.
Dark gray nodular ss.
Olive green, very thin bedded chippy sh.
Dark gray ss.
Gray-black ss.
Gray, brown to red, nodular ss.
Blue-gray fine grained siltstone interbedded with gray to black sh. Sparse fauna.
Olive green sh.
Gray siltstone.
Olive green sh.
Gray, soft silts with green sh.
Gray-green sh.
Soft, gray, nodular silts with soft blue-gray to black sh.
Thin bedded, blue-gray, nodular ls.
ALAMOGORDO
Massive, fine grained, hard, black ls. with occasional white chert nodules.
Hard, massive, black ls. with black and white banded chert.
Massive, hard, black ls. with occasional dark chert nodules.
ANDRECITO
Black to blue-gray, hard ls. without chert.
Crinoidal ls.
Gray-green, silty sh.
Gray-green nodular ss. interbedded with silty sh.
Soft gray sh.
Gray-green ss.
Soft gray sh.
Gray to green, soft, nodular ss. interbedded with green, paper thin sh. beds.
Olive green sh.
Coarse grained, red to brown, quartz ss.
Red to gray chert cong.
Reworked chert cong. in sandy sh.
TIERRA BLANCA
Massive, cross-bedded Crequina carrying white chert.
Local bioherm structures.
NUNN
Soft blue-gray marl.
Blue-gray, cherty, fossiliferous crinoidal ls. carrying Cactocrinus and Dorycrinus.
Soft, blue-gray, crinoidal marl. Stegonocrinus, Amphorocrinus, and Spirifer rowleyi.
Hard, gray crinoidal ls.
Blue-gray marl.

FIGURE 25.—*Rhodes Canyon section*

Center SE¼, SW¼, Sec. 4, T 13 S, R 4 E.

at an extensively deformed area and there are no exposures. However, good exposures are present on both canyon walls above the mouth of the canyon. The measured section (Fig. 25) is located on the north canyon wall near the mouth.

Devonian sediments are excellently developed in the Rhodes Canyon area. Onate, Sly Gap, and Contadero sediments are present. The Contadero is unusually well-developed here and contains many thin beds of sandstone.

The Andrecito member of the Lake Valley formation rests unconformably on the Contadero surface. No Caballero sediments are present. A few feet of thin-bedded, dark-gray limestone at the base of the Alamogordo member may represent the Andrecito member. It is apparent that the Lake Valley formation overlaps toward the north and that only the uppermost portion of the Andrecito member is represented in this section, if at all.

The Alamogordo member is slightly over 30 feet of black, hard, massive, fine-grained, sparsely fossiliferous, cherty limestone.

The Nunn member is well but thinly developed and consists of interbedded blue-gray marls and crinoidal limestones. Typical Nunn fossils such as *Spirifer rowleyi*,

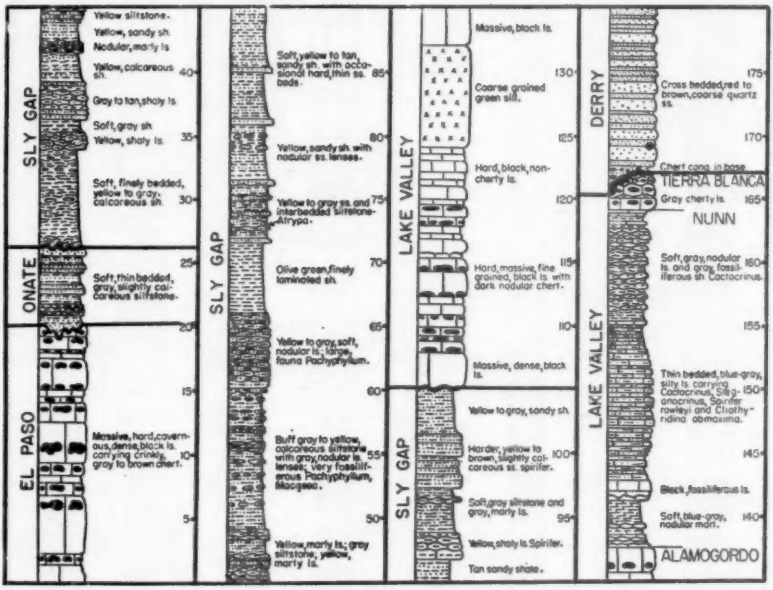
SLY GAP
ONATE
EL PASO
Yellow siltstone.
Yellow, sandy sh.
Nodular, marly ls.
Yellow, calcareous sh.
Gray to tan, shaly ls.
Soft, gray sh.
Yellow, shaly ls.
Soft, finely bedded, yellow to gray, calcareous sh.
Soft, thin bedded, gray, slightly calcareous siltstone.
Massive, hard, cavernous, dense, black ls. carrying crinkly gray to brown chert.
SLY GAP
Soft, yellow to tan, sandy sh. with occasional hard, thin ss. beds.
Yellow, sandy sh. with nodular ss. lenses.
Yellow to gray ss. and interbedded siltstone-Atrypa.
Olive green, finely laminated sh.
Yellow to gray, soft, nodular ls., large, fauna Pachyphyllum.
Buff gray to yellow, calcareous siltstone with gray, nodular ls. lenses. Very fossiliferous Pachyphyllum, Mooreoa.
Yellow, marly ls.; gray siltstone, yellow, marly ls.
LAKE VALLEY
SLY GAP
Massive, black ls.
Coarse grained green sltst.
Hard, black, non-cherty ls.
Hard, massive, fine grained, black ls. with dark nodular chert.
Massive, dense, black ls.
Yellow to gray, sandy sh.
Hard; yellow to brown, slightly calcareous ss. spirifer.
Soft, gray siltstone and gray, marly ls.
Yellow, shaly ls. Spirifer.
Tan sandy shale.
DERRY
LAKE VALLEY
Cross bedded, red to brown, coarse quartz ss.
Chert cong. in base
TIERRA BLANCA
Gray cherty ls.
NUNN
Soft, gray, nodular ls. and gray, fossiliferous sh. Cactocrinus.
Thin bedded, blue-gray, silty ls. carrying Cactocrinus, Stegnocrinus, Spirifer rowleyi and Cliothyridina abmaxima.
Black, fossiliferous ls.
Soft, blue-gray, nodular marl.
ALAMOGORDO

FIGURE 26.—*Sly Gap section*

SW¼, NW¼, Sec. 25, T 11 S, R 5 E.

Dictyoclostus fernglenensis, *Steganocrinus pentagonus*, *Cactocrinus multibrachiatus*, and *Amphoracrinus divergens* were identified from the softer marl beds.

The Nunn is overlain by a thin sequence of Tierra Blanca rocks. Medium-bedded, gray criquina containing white nodular chert forms a low scarp at the top of the Mississippian section. No Arcente or Dona Ana strata were observed in this area. Pennsylvanian conglomerates containing reworked Mississippian cherts directly overlie the Tierra Blanca formation.

Sly Gap section.—Sly Gap is one of the smaller drainage channels which enters the Tularosa basin a few miles south of Sheep Mountain. The measured section (Fig. 26) is located on the south slope of Sheep Mountain.

In this area Contadero sediments, so well represented in the Rhodes Canyon area a few miles to the south, are missing. Mississippian strata rest directly on the eroded surface of the Sly Gap formation (Stevenson, 1945, p. 229).

The Alamogordo member lies at the base of the Mississippian section at Sly Gap. The Caballero formation and the Andrecito member are absent. This fact further demonstrates the transgressive overlap of the Lake Valley formation toward the

north. The Alamogordo member consists of hard, massive, fine-grained, cherty limestone and contains an intruded sill of green basic igneous rock.

The Nunn member consists of blue-gray marls and interbedded, nodular criquina. *Cliothyridina obmaxima*, *Spirifer rowleyi*, *Steganocrinus pentagonus*, and *Cactocrinus multibrachiatus* were identified at this locality.

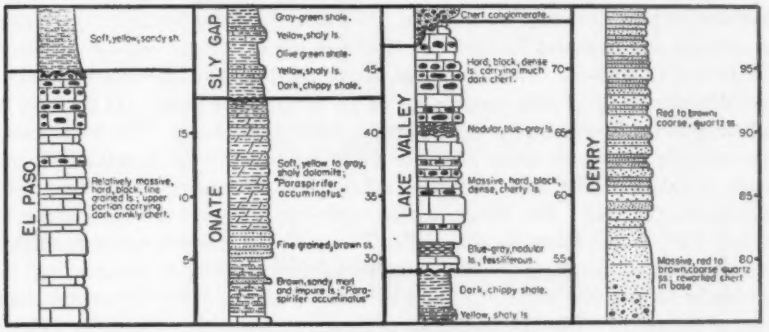

FIGURE 27.—*Mockingbird Gap section*

SW¼, NW¼, Sec. 5, T 10 S, R 5 E.

A very thin sequence of Tierra Blanca limestone of the usual gray criquina filled with weathered white chert is exposed beneath the Pennsylvanian.

Mockingbird Gap section.—Mississippian rocks are very thin in the Mockingbird Gap area. A section was measured (Fig. 27) on the west side of the range just west of the summit near the road that crosses the San Andres Range 2 miles south of Mockingbird Gap.

The Alamogordo member, the only Mississippian unit present, rests unconformably on the eroded Sly Gap and is directly overlain by Pennsylvanian rocks. It consists of typically massive, hard, black, fine-grained, cherty limestone only 20 feet thick. *Dictyoclostus fernglenensis* and *Spirifer rowleyi* were collected from a soft marly zone near the base.

OSCURA MOUNTAINS

No Mississippian rocks were found in the Oscura Mountains which lie a few miles northeast of Mockingbird Gap. At one exposure minor amounts of vitreous white chert were found in the base of the Pennsylvanian. Possibly this chert was reworked from Mississippian strata.

MIMBRES RANGE

Summary.—Mississippian rocks rest on the nodular, gray, fossiliferous calcareous shales of the Box[2] member of the Percha shale. The thickness of the Box member

[2] The names Ready Pay and Box were proposed by Stevenson (1945, p. 241) for units of the Percha shale in the Mimbres Range. Keyes (1906) proposed names for units of the Devonian and Mississippian in the same area. However, his units were poorly defined, type localities were vaguely referred to and Keyes himself subsequently so misused the names that they are best discarded. Stainbrook (1947, p. 298) is not accurate in thinking "—that these names were proposed for identical divisions of the Percha."

varies slightly probably because of pre-Mississippian erosion. The Caballero formation, so well represented in the San Andres and Sacramento Mountains is absent in all but a small portion of the Mimbres Range (Fig. 28). A thin sequence of Caballero rocks in the immediate area of Lake Valley thins rapidly to the north and can be traced to the vicinity of Wilson's Ranch (Fig. 41). These rocks are not exposed in the southern end of the Mimbres Range but thin in that direction since they are not present in the Cooks Range. The Andrecito member is feebly developed all through the Mimbres Range. Its thickness varies slightly because of relief on the Devonian surface. The Alamogordo member, typically developed throughout the Mimbres Range, forms massive scarps all through the range. It thickens considerably in the Hermosa area in the northern part of the range. The Nunn member is excellently developed in the Mimbres Range where the sections reach their maximum thickness. The soft blue-gray marls produce remarkable crinoid faunas throughout the area. The Nunn member thins slowly toward the north and is only 33 feet thick in the Hermosa area. The Tierra Blanca member varies in thickness because of pre-Pennsylvanian erosion in the southern portion of the area, and thins gradually toward the north. The rocks referred to the Kelly formation thicken toward the north. Studies in the Santa Rita area show that the Kelly limestone also thickens in that direction.

General description.—The Mimbres Range is broadly anticlinal and is extensively complicated by faulting. Mississippian rocks are exposed along the eastern foothills of the Mimbres Range from the vicinity of Chloride on the north to the Lake Valley area on the south. In general, the sedimentary rocks dip eastward away from the range and crop out with erosional escarpments facing toward the range. In the southern part of the area, from Hillsboro south to Lake Valley, the sequence is repeated several times by a series of north-south strike faults that roughly parallel the east side of the range. Throughout the area of exposure, local oblique faults offset the bands of strata, greatly complicating the problem of tracing beds. In the southern part of the range Tertiary volcanic rocks occupy large areas in which Mississippian rocks would normally be expected.

Mississippian stratigraphy is relatively simple in the Mimbres Range. Caballero sediments are absent except in the vicinity of Lake Valley. The Lake Valley formation represented by the Andrecito, Alamogordo, Nunn, and Tierra Blanca members only. Rocks tentatively referred to the Kelly formation occur mainly in the northern and possibly the southwestern parts of the area. No rocks of Las Cruces, Rancheria, or Helms age have been found.

Lake Valley Type section.—Mississippian rocks rest unconformably on the nodular gray shale beds of the Box member of the Percha formation at Lake Valley (Fig. 29). The Caballero formation, 48 feet thick, lies at the base of the Mississippian section. The basal beds consist of very thin-bedded, brown, sandy limestone. The contact is sharp and easily distinguishable, because the hard, resistant basal beds crop out as a low scarp. The upper part of the Caballero formation consists of soft, gray, nodular limestone interbedded with soft, gray shale. Fossils identified from the Caballero formation at Lake Valley are: *Rhipidomella missouriensis, Chonetes glenparkensis, Productina sampsoni, Schizophoria chouteauensis, Dielasma* sp.,

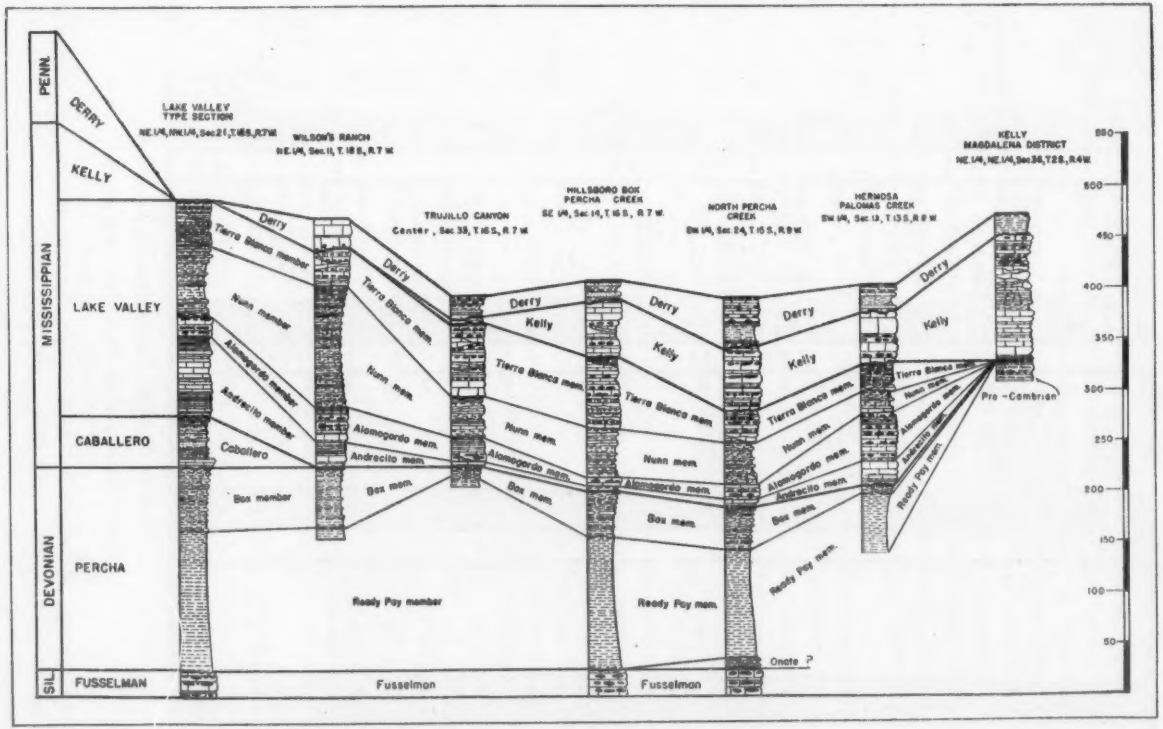

FIGURE 28.—*Correlation of sections—Mimbres and Kelly areas*

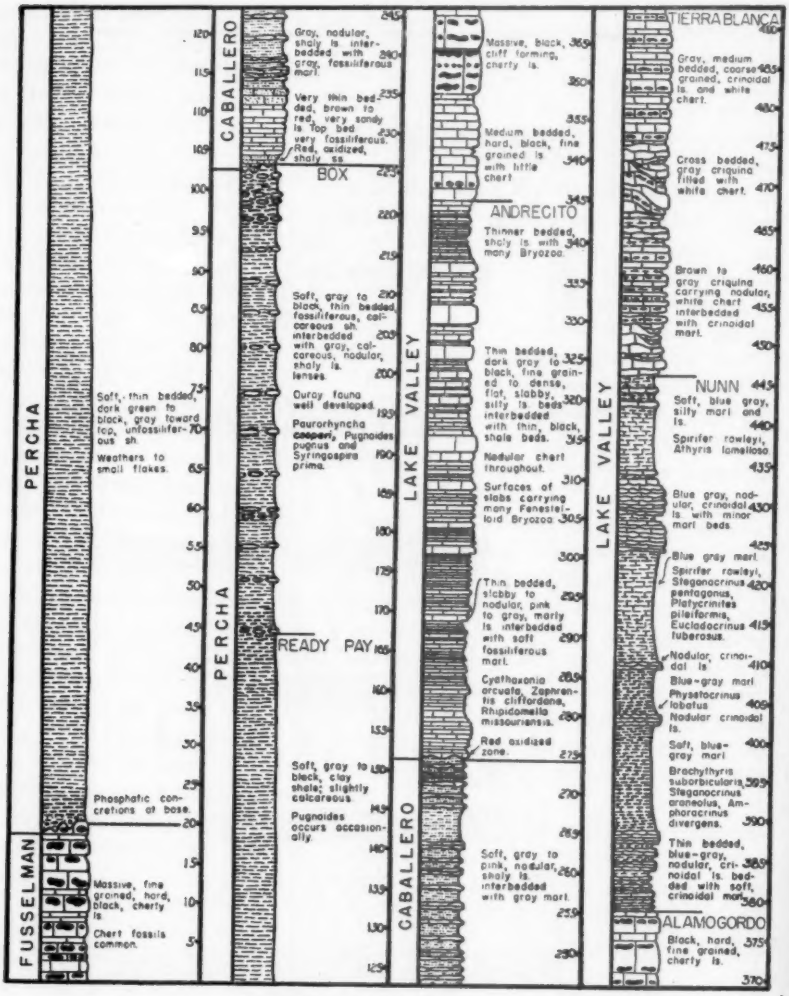
FUSSELMAN
PERCHA
CABALLERO
PERCHA
LAKE VALLEY
CABALLERO
LAKE VALLEY
TIERRA BLANCA
NUNN
ALAMOGORDO
BOX
ANDRECITO
READY PAY
Soft, thin bedded, dark green to black, gray toward top, unfossiliferous sh.
Weathers to small flakes.
Phosphatic concretions at base.
Massive, fine grained, hard, black, cherty ls.
Chert fossils common.
Gray, nodular, shaly ls. interbedded with gray, fossiliferous marl
Very thin bedded, brown to red, very sandy ls. Top bed very fossiliferous.
Red, oxidized, shaly ss.
Soft, gray to black, thin bedded, fossiliferous, calcareous sh. interbedded with gray, calcareous, nodular, shaly ls. lenses.
Ouray fauna well developed.
Paurorhyncha cooperi, Pugnoides pugnus and Syringospira prima.
Soft, gray to black, clay shale; slightly calcareous.
Pugnoides occurs occasionally.
Massive, black, cliff forming, cherty ls.
Medium bedded, hard, black, fine grained ls. with little chert
Thinner bedded, shaly ls. with many Bryozoa
Thin bedded, dark gray to black, fine grained to dense, flat, slabby, silty ls. beds interbedded with thin, black, shale beds.
Nodular chert throughout.
Surfaces of slabs carrying many Fenestella Bryozoa
Thin bedded, slabby to nodular, pink to gray, marly ls. interbedded with soft fossiliferous marl.
Cyathaxonia arcuata, Zaphrentis cliffordana, Rhipidomella missouriensis.
Red oxidized zone.
Soft, gray to pink, nodular, shaly ls. interbedded with gray marl.
Gray, medium bedded, coarse grained, crinoidal ls. and white chert.
Cross bedded, gray crinoina filled with white chert.
Brown to gray crinoina carrying nodular, white chert interbedded with crinoidal marl.
Soft, blue gray, silty marl and ls.
Spirifer rowleyi, Athyris lamellosa
Blue gray, nodular, crinoidal ls. with minor marl beds
Blue gray marl
Spirifer rowleyi, Steganocrinus pentagonus, Platycrinites pileiformis, Eucladocrinus tuberosus.
Nodular, crinoidal ls.
Blue-gray marl
Physetocrinus lobatus
Nodular crinoidal ls.
Soft, blue-gray marl
Brachythyris suborbicularis, Steganocrinus granulus, Amphoracrinus divergens.
Thin bedded, blue-gray, nodular, crinoidal ls. bedded with soft, crinoidal marl
Black, hard, fine grained, cherty ls.

FIGURE 29.—*Lake Valley type section*

Lake Valley, New Mexico, NE¼, NW¼, Sec. 21, T 18 S, R 7 W.

Camarotoechia sp., *Rhynchopora hamburgensis, Spirifer platynotus, S. gregeri, S. louisianensis, Cliothyridina tenuilineata, Ambocoelia minuta,* and *Nucleospira rowleyi.* All these species occur in the Caballero formation in the Sacramento Mountains.

The Andrecito member of the Lake Valley formation overlies the Caballero unconformably. A red oxidized, shaly zone marks the contact, and the strata immediately above the contact are evenly bedded. The basal beds of the Andrecito

member are quite similar lithologically to the underlying Caballero formation apparently because of the presence of reworked Caballero sediments. The authors (Laudon and Bowsher, 1941, p. 2157) previously placed all of the Andrecito member in the Caballero formation. The Andrecito member consists of 71 feet of thin-bedded, gray limestone with thin shale partings. The beds in the middle part of the section are slightly more massive than lower or upper parts. Fossils, with the exception of fenestelloid bryozoans, are not abundant. *Cyathaxonia arcuata, Zaphrentis cliffordana, Rhipidomella missouriensis,* and *Dictyoclostus fernglenensis* were identified from the basal beds. *Fenestella, Penniretepora, Rhombopora, Leioclema, Hernodia, Lichenotrypa,* and *Thamniscus* were found in higher beds just beneath the Alamogordo member.

The Alamogordo member, 33 feet thick, overlies the Andrecito member conformably, with gradational contact, the massive, hard, black, fine-grained, sparsely fossiliferous, cherty limestone of the Alamogordo making a conspicuous scarp along the mountain front.

The Nunn member, 65 feet thick, overlies the Alamogordo member conformably and consists of nodular, blue-gray criquina and soft, blue-gray, crinoidal marl. The upper part is interbedded with brown and gray criquina and contains the prolific Lake Valley crinoid fauna (Wachsmuth and Springer, 1897). More than half of the species in the fauna are undescribed, but some of the more common fossils are *Zaphrentis centralis, Caninia arcuta, Rhodocrinites wortheni, Cactocrinus* cf. *C. multibrachiatus* (?), *Cactocrinus* (?) cf. *C. extensus, Amphoracrinus divergens, Steganocrinus pentagonus, S. araneolus, Physetocrinus lobatus, Platycrinites peculiarie, P. nodostriatus, P. burlingtonensis, P. subspinosus, P. springeri, P. pocilliformis, Eucladocrinus tuberosus, Dictyoclostus fernglenensis, Rhipidomella oweni, Schizophoria poststriatula, Leptaena analoga, Rhynchopora persinuata, Spirifer rowleyi, S. louisianensis, Syringothyris texta, Tylothyris novamexicana, Athyris lamellosa, Cliothyridina glenparkensis, Cliothyridina obmaxima, Phillipsia sampsoni,* and *P. obesa.* Most abundant are new species of *Cactocrinus* and primitive actinocrinitids. The stage of evolution represented by the crinoids is definitely early Osage and appears to represent a fauna older than that of the lower Burlington. Similar Actinocrinitids are known only from the Fern Glen formation of Missouri.

The Tierra Blanca member caps the section at Lake Valley. The soft marls of the Nunn member gradually become interbedded with gray, coarse-grained criquina so that no exact contact can be drawn between the two members. The Tierra Blanca is medium-bedded, hard, gray to brown, coarse-grained criquina that carries considerable light-colored nodular chert. Fossils, other than crinoid fragments, are not abundant. Large brachiopods such as *Spirifer rowleyi,* and *Cliothyridina obmaxima,* are the most common. Approximately 50 feet of the Tierra Blanca member is exposed at Lake Valley, but as the formation dips eastward under the relatively flat foothills area and the Pennsylvanian contact is not exposed, the member may be considerably thicker.

Berenda Canyon section.—Mississippian rocks are excellently exposed a few miles north of Berenda Canyon, midway between Berenda and Tierra Blanca Creeks. Here escarpments of Mississippian rocks face inward toward the Mimbres Range

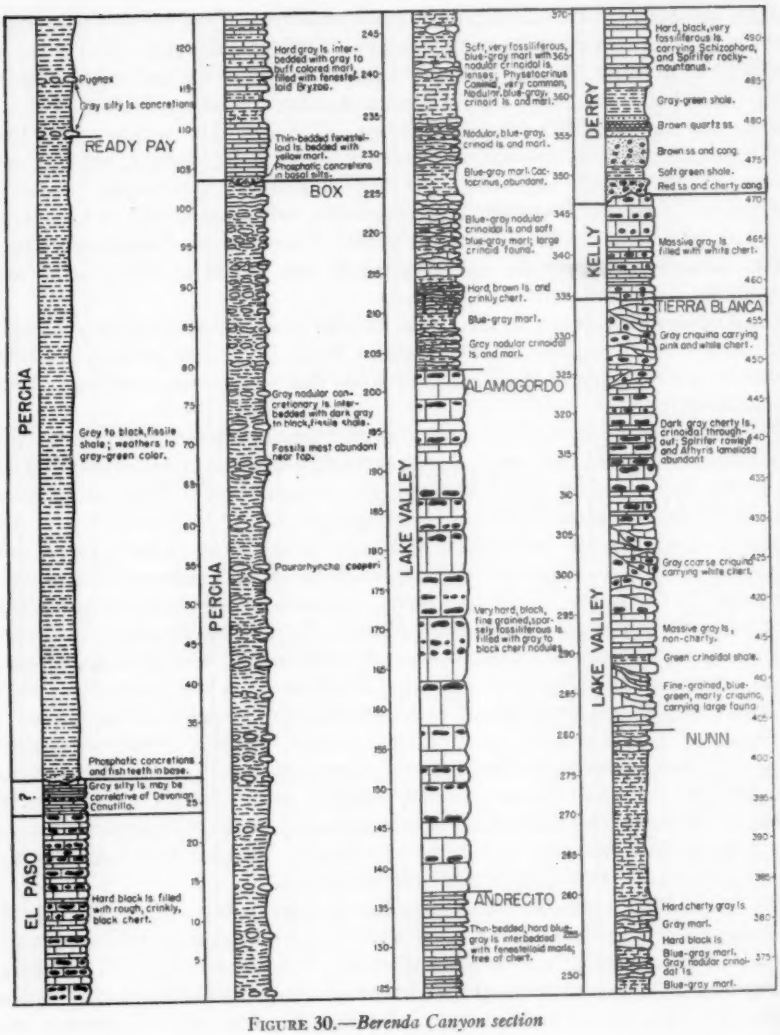
EL PASO
?
PERCHA
READY PAY
Pugnax
Gray silty ls. concretions
Grey to black, fissile shale; weathers to grey-green color.
Phosphatic concretions and fish teeth in base.
Grey silty ls. may be correlative of Devonian Contutilo.
Hard black ls. filled with rough, crinkly, black chert.
PERCHA
BOX
Hard gray ls. interbedded with gray to buff colored marl, filled with fenestel. laid Bryzoa.
Thin-bedded fenestellaid ls. bedded with yellow marl. Phosphatic concretions in basal silts.
Gray nodular concretionary ls. interbedded with dark gray to black, fissile shale.
Fossils most abundant near top.
Pourarhyncha cooperi
LAKE VALLEY
Soft, very fossiliferous, blue-gray marl with nodular crinoidal ls. lenses; Physetocrinus Ceanna, very common. Nodular, blue-gray crinoid ls. and marl.
Nodular, blue-gray crinoid ls. and marl.
Blue-gray marl. Cactocrinus, abundant.
Blue-gray nodular crinoidal ls. and soft blue-gray marl; large crinoid fauna.
Hard, brown ls. and crinkly chert.
Blue-gray marl.
Grey nodular crinoidal ls. and marl.
ALAMOGORDO
Very hard, black, fine grained, sparsely fossiliferous ls. filled with gray to black chert nodules.
ANDRECITO
Thin-bedded, hard blue-gray ls. interbedded with fenestelloid marls; free of chert.
DERRY
KELLY
LAKE VALLEY
Hard, black, very fossiliferous ls. carrying Schizophoria, and Spirifer rockymountanus.
Gray-green shale.
Brown quartz ss.
Brown ss and cong.
Soft green shale.
Red ss and cherty cong.
Massive gray ls. filled with white chert.
TIERRA BLANCA
Gray crinuina carrying pink and white chert.
Dark gray cherty ls., crinoidal throughout; Spirifer rowleyi and Athyris lamellosa abundant.
Gray coarse crinoid carrying white chert.
Massive gray ls., non-cherty.
Green crinoidal shale.
Fine-grained, blue-green, marly crinuina, carrying large fauna.
NUNN
Hard cherty gray ls.
Gray marl.
Hard black ls.
Blue-gray marl.
Gray nodular crinoidal ls.
Blue-gray marl.

FIGURE 30.—*Berenda Canyon section*

Center of West Line, Sec. 29, R 7 W, T 17 S.

and can be traced for several miles. The section measured (Fig. 30) is located on a bold escarpment in Section 29 a few miles north of Berenda Canyon.

The Andrecito member of the Lake Valley formation lies at the base of the Mississippian section resting on the eroded upper surface of the Box member of the Percha shale. Because the underlying Percha shale is soft, the basal beds of the Andrecito form a prominent escarpment. The latter member consists of 28 feet

of very thin-bedded, gray, fossiliferous limestones with thin shale partings. The surfaces of these thin basal beds are crowded with fenestelloid bryozoans.

The Alamogordo member, approximately 65 feet of massive, hard, fine-grained, poorly fossiliferous, cherty limestone, forms a prominent escarpment along the mountain front. One zone contains concentrically banded black and white chert nodules.

The Nunn member, 80 feet thick, forms a retreating, rubbly slope along the mountain front. It consists of the usual nodular, thin-bedded, criquina interbedded with soft, blue-gray marl beds, the latter making up most of the sequence near the top of the member. Typical Nunn fossils have been identified from the beds but are not as abundant as at Lake Valley. *Caninia arcuta*, *Cactocrinus* (?) cf. *C. extensus*, *Steganocrinus pentagonus*, *Spirifer rowleyi*, and *Athyris lamellosa* have been identified.

The Tierra Blanca member, 53 feet thick, overlies the Nunn member conformably. The contact is sharp, and the basal beds are not interbedded with blue-gray marl. It consists of medium-bedded, coarse-grained, gray criquina with white chert nodules in the upper portion. Small local biohermal structures are developed throughout the member.

Approximately 12 feet of strata are tentatively referred to the Kelly formation in this area. They consist of massive, evenly-bedded, gray, slightly crinoidal limestone beds containing small rounded chert nodules. The Kelly formation appears to lie conformably on the Tierra Blanca member in the Berenda Canyon area, but it is probably disconformable. No identifiable fossils were found. The beds are referred to the Kelly formation entirely on the basis of lithologic features and stratigraphic position. In general, they are very much like the underlying Tierra Blanca, and possibly they should have been included in that member. The Kelly strata are unconformably overlain by Pennsylvanian sandstone and conglomerate.

Tierra Blanca Canyon section.—Mississippian rocks are excellently exposed on both canyon walls on Tierra Blanca Creek just upstream from the Pryor Nunn Ranch. The measured section (Fig. 31) lies on the north wall.

The Andrecito member of the Lake Valley formation lies at the base of the Mississippian section and rests unconformably on the nodular shaly limestone beds of the Box member of the Percha shale. It consists of less than 10 feet of very thin-bedded, gray fossiliferous limestone interbedded with soft shale. Fenestelloid bryozoans crowd the surfaces of limestone slabs from the lower part of the zone.

The Alamogordo member, approximately 28 feet of hard, massive, black, cherty limestone, is slightly thinner than in Berenda Canyon to the south. As usual, it forms a persistent escarpment along the mountain front and contains a zone of characteristic concentrically banded, black and white chert nodules.

The Nunn member, 110 feet thick, forms a highly weathered, retreating, rubbly slope with occasional exposures of blue-gray, nodular criquina. The soft gray marl beds make up the major part of the member here. Crinoid fossils occur in profusion on the weathered slopes. Well over half of the species are undescribed, and in most cases appear to be ancestral to known Burlington species. Some of the commonly occurring species are: *Rhodocrinites wortheni*, *Cactocrinus* (?) cf. *C. extensus*, *Cacto-*

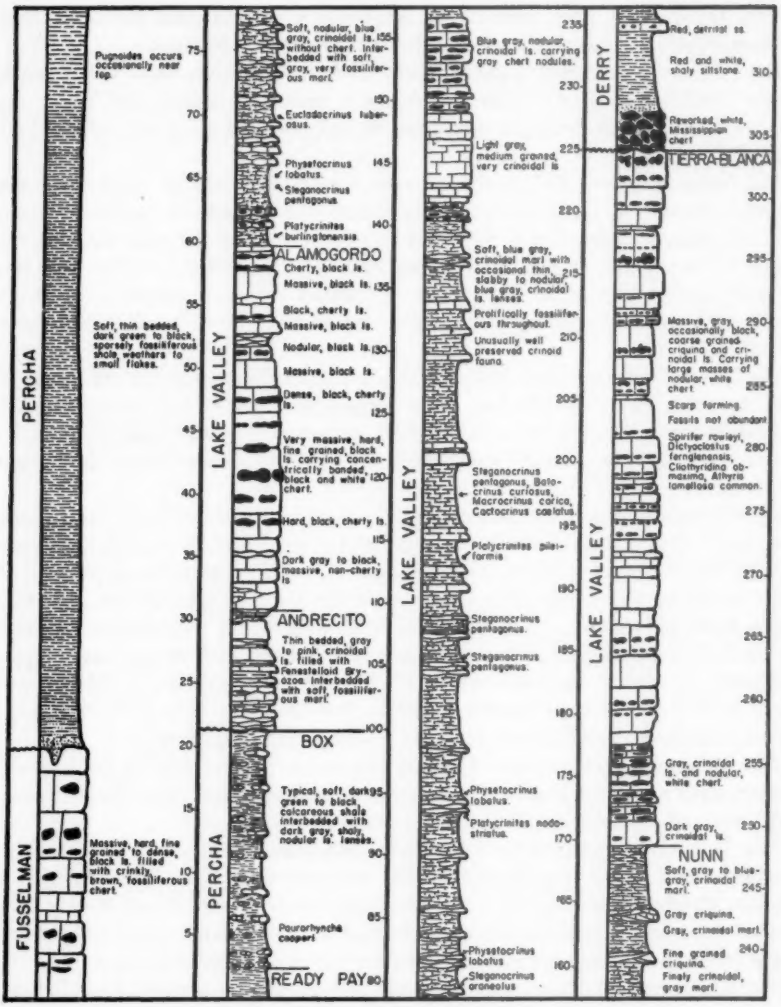
PERCHA
FUSSELMAN
Pugnoides occurs occasionally near top.
Soft, thin bedded, dark green to black, sparsely fossiliferous shale weathers to small flakes.
Massive, hard, fine grained to dense, black ls. filled with crinkly, brown, fossiliferous chert.
LAKE VALLEY
PERCHA
Soft, nodular, blue gray, crinoidal ls. without chert. Interbedded with soft, gray, very fossiliferous marl.
Euclastocrinus tuberosus.
Physetocrinus lobatus.
Steganocrinus pentagonus
Platycrinites burlingtonensis.
ALAMOGORDO
Cherty, black ls.
Massive, black ls.
Black, cherty ls.
Massive, black ls.
Nodular, black ls.
Massive, black ls.
Dense, black, cherty ls.
Very massive, hard, fine grained, black ls. carrying concentrically banded, black and white chert.
Hard, black, cherty ls
Dark gray to black, massive, non-cherty ls
ANDRECITO
Thin bedded, gray to pink, crinoidal ls. filled with Fenestelloid Bryozoa. Interbedded with soft, fossiliferous marl.
BOX
Typical, soft, dark green to black, calcareous shale interbedded with dark gray, shaly, nodular ls. lenses.
Pourorhynchs cooperi
READY PAY
LAKE VALLEY
Blue gray, nodular, crinoidal ls. carrying gray chert nodules.
Light gray, medium grained, very crinoidal ls
Soft, blue gray, crinoidal marl with occasional thin, slabby to nodular, blue gray, crinoidal ls. lenses.
Prolifically fossiliferous throughout.
Unusually well preserved crinoid fauna.
Steganocrinus pentagonus, Batocrinus curiosus, Macrocrinus carica, Cactocrinus coelatus.
Platycrinites pileiformis
Steganocrinus pentagonus.
Steganocrinus pentagonus.
Physetocrinus lobatus.
Platycrinites nodostriatus.
Physetocrinus lobatus
Steganocrinus graneolus
LAKE VALLEY
DERRY
Red, detrital ss.
Red and white, shaly siltstone.
Reworked, white, Mississippian chert
TERRA BLANCA
Massive, gray, occasionally black, coarse grained criquina and crinoidal ls. Carrying large masses of nodular, white chert.
Scarp forming.
Fossils not abundant
Spirifer rowleyi, Dictyoclostus ferngleanensis, Cleithyridina obmaxima, Athyris lamellosa common.
Gray, crinoidal ls. and nodular, white chert.
Dark gray, crinoidal ls.
NUNN
Soft, gray to blue-gray, crinoidal marl.
Gray criquina.
Gray, crinoidal marl.
Fine grained criquina.
Finely crinoidal, gray marl.

FIGURE 31.—*Tierra Blanca Canyon section*

SW¼, NW¼, Sec. 10, T 17 S, R 8 W.

crinus (?) cf. *C. coelatus, Cactocrinus* (?) cf. *C. multibrachiatus, Amphoracrinus divergens, Steganocrinus pentagonus, Physetocrinus lobatus, Macrocrinus carica, Batocrinus curiosus, Platycrinites pileiformis, P. nodostriatus,* and *P. springeri.*

The Tierra Blanca member is 55 feet of hard, scarp-forming, medium-bedded, gray, coarse-grained, crinoidal limestone that carries many large, white chert nodules. Large brachiopods and crinoid fragments are the commonest fossils. The lower por-

tion of the Pennsylvanian which directly overlies the Tierra Blanca, contains minor amounts of reworked Mississippian chert in a red shaly sandstone.

Trujillo Canyon section.—Exposures of Mississippian rocks cross Trujillo Creek on the line of strike directly northwest from the exposures on Tierra Blanca Creek. The

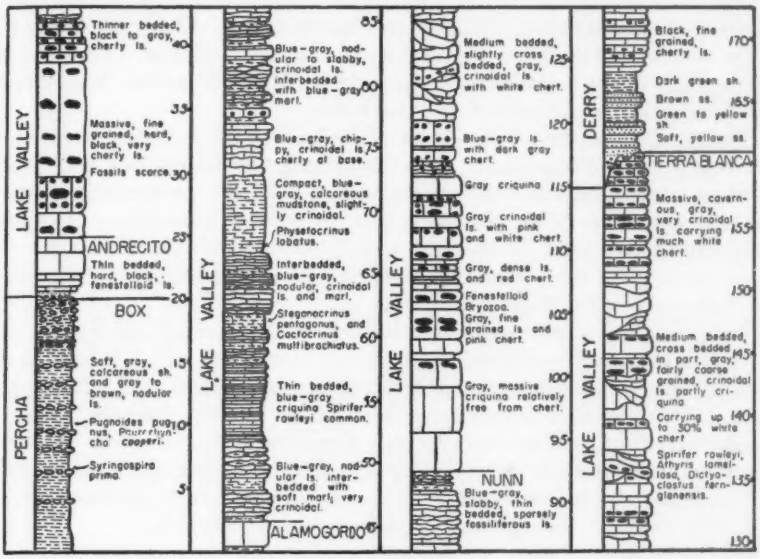
LAKE VALLEY
PERCHA
Thinner bedded, black to gray, cherty ls.
Massive, fine grained, hard, black, very cherty ls.
Fossils scarce
ANDRECITO
Thin bedded, hard, black, fenestelloid ls.
BOX
Soft, gray, calcareous sh. and gray to brown, nodular ls.
Pugnoides pugnus, Pnuerrhyncha cooperi.
Syringospira prima.
LAKE VALLEY
Blue-gray, nodular to slabby, crinoidal ls. interbedded with blue-gray marl.
Blue-gray, chippy, crinoidal ls. cherty at base.
Compact, blue-gray, calcareous mudstone, slightly crinoidal.
Physetocrinus lobatus.
Interbedded, blue-gray, nodular, crinoidal ls. and marl.
Steganocrinus pentagonus, and Cactocrinus multibrachiatus.
Thin bedded, blue-gray criquina Spirifer rowleyi common.
Blue-gray, nodular ls. interbedded with soft marl, very crinoidal.
ALAMOGORDO
LAKE VALLEY
Medium bedded, slightly cross bedded, gray, crinoidal ls. with white chert.
Blue-gray ls. with dark gray chert.
Gray criquina
Gray crinoidal ls. with pink and white chert.
Gray, dense ls. and red chert.
Fenestelloid Bryozoa.
Gray, fine grained ls. and pink chert.
Gray, massive criquina relatively free from chert.
NUNN
Blue-gray, slabby, thin bedded, sparsely fossiliferous ls.
LAKE VALLEY
DERRY
Black, fine grained, cherty ls.
Dark green sh.
Brown ss.
Green to yellow sh.
Soft, yellow ss.
TIERRA BLANCA
Massive, cavernous, gray, very crinoidal ls. carrying much white chert.
Medium bedded, cross bedded in part, gray, fairly coarse grained, crinoidal ls. partly criquina.
Carrying up to 30% white chert
Spirifer rowleyi, Athyris lamellosa, Dictyoclostus farnglenensis.

FIGURE 32.—*Trujillo Canyon section*

Center, Sec. 33, T 16 S, R 8 W.

section measured (Fig. 32) is on the north bank of Trujillo Creek slightly over 2 miles north and a little west from the measured section on Tierra Blanca Creek.

A very thin sequence referable to the Andrecito member rests unconformably on the Percha shale. The Andrecito member overlaps northward and is thin throughout the northern portion of the Mimbres Range. The non-typical thin-bedded, hard, dark-gray limestone, 5 feet thick, not markedly fossiliferous, is placed in the Andrecito member only because it is thin-bedded and chert free.

The Alamogordo member, 20 feet of hard, massive, black, cherty limestone, makes a prominent scarp along the canyon wall.

The Nunn member consists of nodular, blue-gray, marly criquina interbedded with soft marl beds 47 feet thick. The marls are much more prominent in the upper part of the section. The member is normally developed along Trujillo Creek, but fossils are not abundant. A few of the commonly occurring fossils are: *Canina arcuata, Steganocrinus pentagonus, Cactocrinus* (?) cf. *C. multibrachiatus* and *Spirifer rowleyi.*

The Tierra Blanca member, 68 feet thick, consists of medium-bedded, gray, coarse-grained criquina having considerable white chert. The basal beds consist of rather obscurely bedded, very crinoidal limestone. Local biohermal structures occur at

several places near the top. The top layers are slightly more evenly bedded, and contain the small chert nodules characteristic of the Kelly formation. They probably should be referred to the Kelly. These beds are unconformably overlain by soft, red and yellow oxidized sandstone of Pennsylvanian age.

Wilson's Ranch section.—Mississippian rocks strike across Berenda Creek approximately one-half mile east of the house on Wilson's Ranch. They cap the low hills on the south side of the creek just southeast of the ranch buildings. The measured section (Fig. 33) is on a west-facing scarp on the north side of Berenda Creek approximately one-half mile northeast of the ranch house.

The Andrecito member, 20 feet thick, of the Lake Valley formation, rests on the Box member of the Percha shale. It is thin-bedded, very fossiliferous, gray to pink limestone interbedded with soft, fossiliferous marl beds. Large numbers of fenestelloid bryozoans occur on the pink slabs near the base of the sequence. *Fenestella*, *Penniretepora*, *Leioclema*, *Lichenotrypa*, and *Rhombopora* were identified.

The Alamogordo member, massive, hard, fine-grained, black, cherty limestone 34 feet thick, makes a very pronounced scarp.

The Nunn member crops out in low, rounded, weathered hills, and the exposures are limited to the bottoms of small gulleys that channel the area. It consists of a thick sequence of soft, blue-gray, nodular criquina interbedded with soft blue-gray marls, 117 feet thick, which makes up most of the section. Because the area is mantled with chert from the overlying beds, fossils are difficult to collect, but following species were collected: *Batocrinus curiosus*, *Dorycrinus unicornis*, *Cactocrinus* (?) cf. *C. coelatus*, *Physetocrinus lobatus*, *Actinocrinites rubra*, *Amphoracrinus divergens*, *Platycrinites halli*, *P. burlingtonensis*, and *Eucladocrinus tuberosus*.

The Tierra Blanca member, conformably overlying the Nunn member, is not well exposed in the area and must be measured down the dip slope. It consists of massive, coarsely-grained criquina and contains white chert nodules throughout. Local biohermal structures occur in at least two places. Large brachiopods such as *Spirifer rowleyi*, *Dictyoclostus fernglenensis*, and *Athyris lamellosa* occur occasionally.

The Tierra Blanca member is unconformably overlain by Pennsylvanian limestone beds containing reworked fragments of Mississippian chert.

Percha Creek, lower canyon section.—Mississippian rocks are exposed in the hills over the type section (?) of the Percha formation, ½ mile east of Hillsboro on the south side of Percha Creek. A complete section (Fig. 34) was measured along the hills just south of "The Box" of Percha Creek.

No Andrecito was present. This emphasizes the fact that considerable relief was developed on the Devonian surface prior to the deposition of Mississippian rocks. The Box member of the Percha shale has thickened to approximately 40 feet in this area where Andrecito sediments are missing. The Alamogordo member of the Lake Valley formation, 17 feet thick, rests on the Percha shale with marked unconformity. The contact is marked by a dark-gray to brown, silty, carbonaceous shale that contains reworked material from the underlying Percha shale. The basal shale grades upward into a massive, hard, black, fine-grained, cherty limestone.

Nunn strata overlie the Alamogordo member conformably but the contact is sharp. Soft blue-gray marls lie at the base of the Nunn, instead of the transition beds of

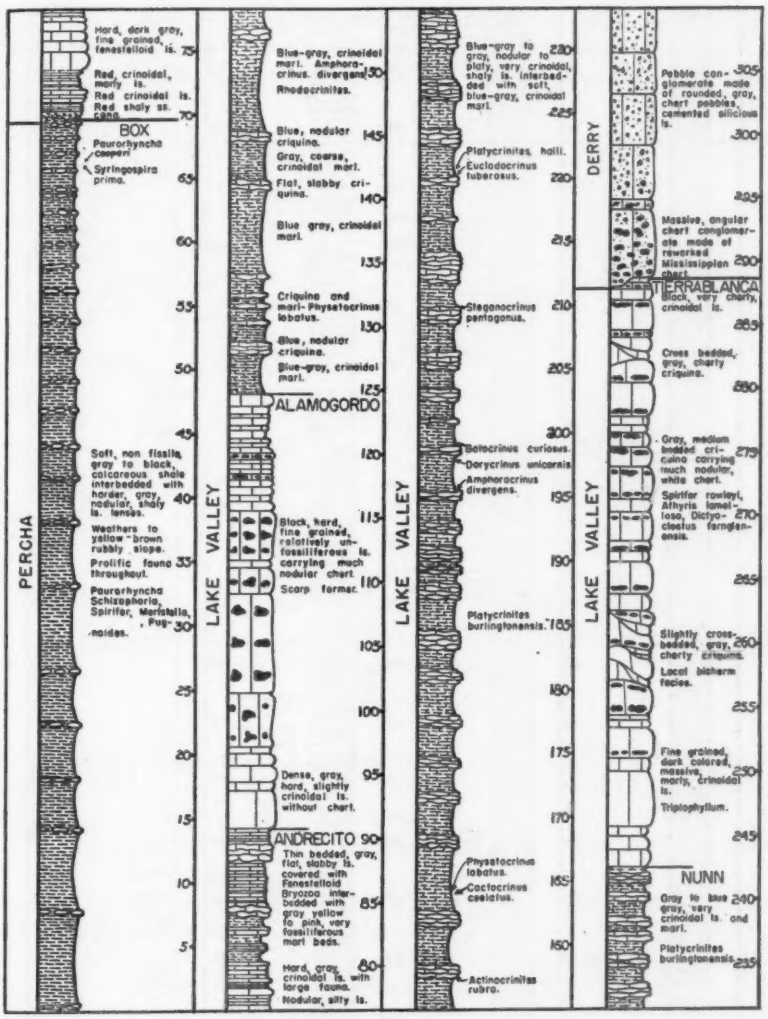
PERCHA
LAKE VALLEY
LAKE VALLEY
LAKE VALLEY
DERRY
BOX
ALAMOGORDO
ANDRECITO
NUNN
TIERRABLANCA
Hard, dark gray, fine grained, fenestelloid ls.
Red, crinoidal, marly ls.
Red crinoidal ls.
Red shaly ss. cong.
Paurorhyncha cooperi
Syringospira prima.
Soft, non fissile, gray to black, calcareous shale interbedded with harder, gray, nodular, shaly ls. lenses.
Weathers to yellow-brown rubbly slope.
Prolific fauna throughout.
Paurorhyncha, Schizophoria, Spirifer, Martiella, Pugnoides.
Blue-gray, crinoidal marl. Amphoracrinus. divergens
Rhodocrinites.
Blue, nodular criquina.
Gray, coarse, crinoidal marl.
Flat, slabby criquina.
Blue gray, crinoidal marl.
Criquina and marl- Physetocrinus lobatus.
Blue, nodular criquina.
Blue-gray, crinoidal marl.
Block, hard, fine grained, relatively unfossiliferous ls. carrying much nodular chert.
Scarp former.
Dense, gray, hard, slightly crinoidal ls. without chert.
Thin bedded, gray, flat, slabby ls. covered with Fenestelloid Bryozoa interbedded with gray yellow to pink, very fossiliferous marl beds.
Hard, gray, crinoidal ls. with large fauna.
Nodular, silty ls.
Blue-gray to gray, nodular to platy, very crinoidal, shaly ls. interbedded with soft, blue-gray, crinoidal marl.
Platycrinites halli.
Eucladocrinus tuberosus.
Steganocrinus pentagonus.
Botocrinus curiosus.
Dorycrinus unicornis.
Amphoracrinus divergens.
Platycrinites burlingtonensis.
Physetocrinus lobatus.
Cactocrinus caelatus.
Actinocrinites rubra.
Pebble conglomerate made of rounded, gray, chert pebbles, cemented siliceous ls.
Massive, angular chert conglomerate made of reworked Mississippian chert.
Black, very cherty, crinoidal ls.
Cross bedded, gray, cherty criquina.
Gray, medium bedded criquina carrying much nodular, white chert.
Spirifer rowleyi, Athyris lamellosa, Dictyoclostus farnglensis.
Slightly cross-bedded, gray, cherty criquina.
Local bioherm facies.
Fine grained, dark colored, massive, marly, crinoidal ls.
Triplophyllum.
Gray to blue gray, very crinoidal ls. and marl.
Platycrinites burlingtonensis.

FIGURE 33.—*Wilson's Ranch section*

NW¼, NE¼, Sec. 11, T 18 S, R 7 W.

crinoidal limestone that are common elsewhere. The Nunn member becomes 50 feet in thickness and is lithologically similar to the type Nunn at Lake Valley. *Caninia arcuta, Rhodocrinites wortheni, Cactocrinus* (?) cf. *C. multibrachiatus, Amphoracrinus divergens, Steganocrinus pentagonus, S. araneolus, Physetocrinus lobatus, Platycrinites pocilliformis, Spirifer rowleyi,* and *Cliothyridina obmaxima* were collected.

Tierra Blanca limestone, 120 feet thick, directly overlies the Nunn member. Ex-

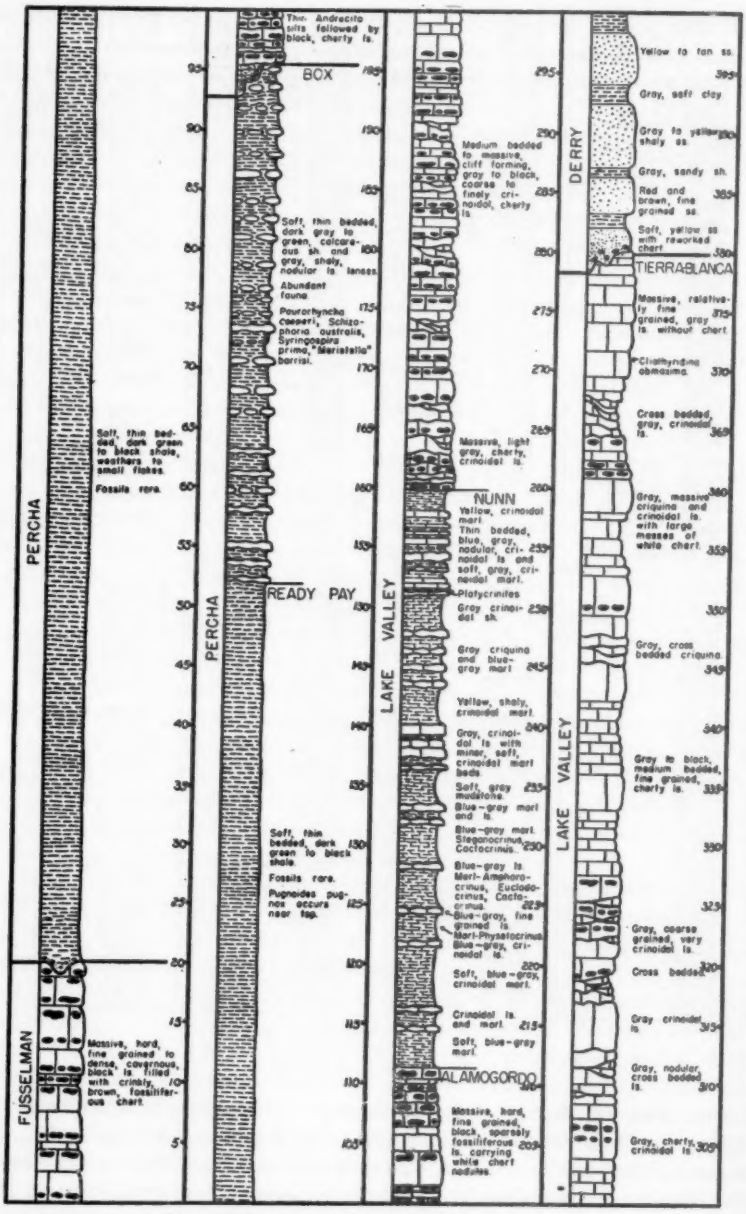
FUSSELMAN
PERCHA
BOX
PERCHA
READY PAY
LAKE VALLEY
NUNN
LAKE VALLEY
ALAMOGORDO
DERRY
TIERRA BLANCA
Massive, hard, fine grained to dense, cavernous, black ls filled with crinoly, brown, fossiliferous chert.
Soft, thin bedded, dark green to black shale, weathers to small flakes.
Fossils rare.
Thin Andrecito silts followed by black, cherty ls.
Soft, thin bedded, dark gray to green, calcareous sh. and gray, shaly, nodular ls lenses.
Abundant fauna
Pourorhyncha coeperi, Schizophoria australis, Syringospira prima, "Meristella" barrisi.
Soft, thin bedded, dark green to black shale.
Fossils rare.
Pugnoides pugnox occurs near top.
Medium bedded to massive, cliff forming, gray to black, coarse to finely crinoidal, cherty ls.
Massive, light gray, cherty, crinoidal ls.
Yellow, crinoidal marl
Thin bedded, blue, gray, nodular, crinoidal ls and soft, gray, crinoidal marl.
Platycrinites
Gray crinoidal sh.
Gray crinoidal and blue-gray marl
Yellow, shaly, crinoidal marl.
Gray, crinoidal ls with minor, soft, crinoidal marl beds.
Soft, gray mudstone.
Blue-gray marl and ls.
Blue-gray marl. Steganocrinus, Cactocrinus.
Blue-gray ls. Marl-Amphoracrinus, Eucladocrinus, Cactocrinus.
Blue-gray, fine grained ls. Marl-Physetocrinus.
Blue-gray, crinoidal ls.
Soft, blue-gray, crinoidal marl.
Crinoidal ls and marl.
Soft, blue-gray marl.
Massive, hard, fine grained, black, sparsely fossiliferous ls. carrying white chert nodules.
Yellow to tan ss.
Gray, soft clay
Gray to yellow shaly ss.
Gray, sandy sh.
Red and brown, fine grained ss.
Soft, yellow ss with reworked chert
Massive, relatively fine grained, gray ls. without chert
Cleithrynina obmaxima.
Cross bedded, gray, crinoidal ls.
Gray, massive crinoina and crinoidal ls. with large masses of white chert.
Gray, cross bedded crinoina.
Gray to black, medium bedded, fine grained, cherty ls.
Gray, coarse grained, very crinoidal ls.
Cross bedded
Gray crinoidal ls.
Gray, nodular, cross bedded ls.
Gray, cherty, crinoidal ls

FIGURE 34.—*Percha Creek, Lower Canyon section*

SE¼, Sec. 14, T 16 S, R 7 W.

cellent evidence of the relief on the Mississippian surface at the beginning of the Pennsylvanian period is observed if this section is compared with the one on Percha Creek Fork a few miles to the northwest where the Tierra Blanca sediments are only 35 feet thick.

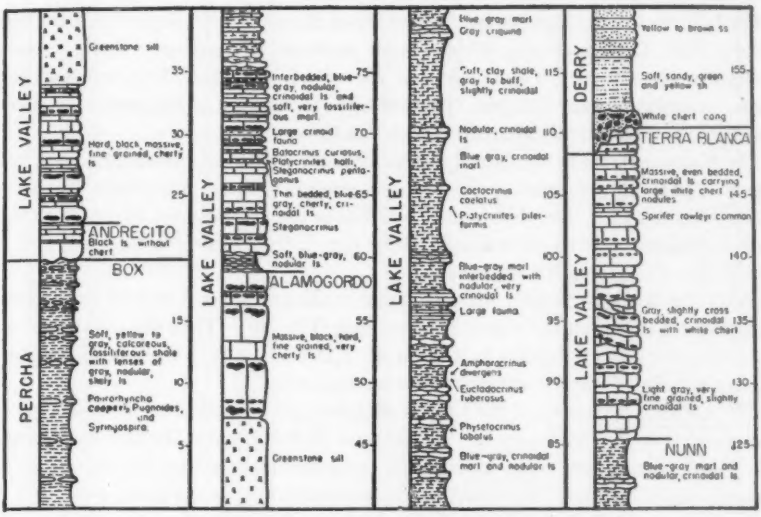

FIGURE 35.—*Percha Creek Fork section*

SE¼, Sec. 9, T 16 S, R 8 W.

The Tierra Blanca member is medium-bedded, gray criquina that contains considerable amounts of nodular white chert. The upper part is more massive and contains less chert. Well-preserved fossils are rare.

The Tierra Blanca member is unconformably overlain by Pennsylvanian sandstone which carries some reworked chert.

Percha Creek Fork section.—Mississippian rocks are excellently exposed along both walls of Percha Creek just downstream from the fork in Percha Creek 2½ miles downstream from Kingston. The measured section (Fig. 35) was located on the south canyon wall. Because this section is located fairly close to the main Percha Creek section east of Hillsboro, it has not been included in the correlation chart (Fig. 42).

The Andrecito member, abnormal in this area, consists of a 3-foot bed of fairly massive, noncherty limestone which is classed with the Andrecito because it does not have the cherts typical of the Alamogordo member. It rests unconformably on the Box member of the Percha shale, and from variations in thickness in the Mimbres range, it can be assumed that the surface on which the Andrecito was laid down had considerable relief.

Approximately 38 feet of section is assigned to the Alamogordo member but a sill of igneous rock 18 feet thick lies in the center so the total thickness is actually not

much greater than normal. It consists of massive, black, cherty limestone, typical of the member.

The basal part of the Nunn member contains a thick sequence of nodular, crinoidal limestone layers interbedded with soft, blue-gray marl grading upward into typical soft, blue-gray marl with crinoidal limestone lenses.

The following Nunn fossils were collected from the weathered slopes along the north canyon wall: *Canina arcuta*, *Rhodocrinites wortheni*, *Cactocrinus* (?) cf. *C. multibrachiatus*, *Cactocrinus* (?) cf. *C. coelatus*, *Physetocrinus lobatus*, *Steganocrinus pentagonus*, *Amphoracrinus divergens*, *Platycrinites pocilliformis*, *Eucladocrinus pleuroviminus*, *Spirifer rowleyi*, and *Dictyoclostus fernglenensis*.

The Nunn member is overlain by approximately 35 feet of medium-bedded, gray, cherty, Tierra Blanca limestone. Pennsylvanian strata rest unconformably on the Tierra Blanca beds. The thin sequence of Tierra Blanca indicates that pre-Pennsylvanian erosion removed all strata of Kelly age, if they were ever present, and cut deeply into the Tierra Blanca member.

North Percha Creek section.—Mississippian rocks are exposed in bold escarpments along several tributaries of North Percha Creek (Fig. 36). They dip toward the east and plunge beneath the valley in Section 30, T.15 S., R. 9 W. Because the region is heavily wooded, complete exposures are not common.

The Andrecito member of the Lake Valley formation rests unconformably on the Box member of the Percha shale. Unlike most of the contacts the first bed is a massive, hard, dense, cherty limestone. It is immediately succeeded by soft, thin-bedded, shaly, limestone beds having the fenestelloid bryozoan fauna typical of the Andrecito member. Less than 10 feet of beds can be assigned to this member, perhaps because the Box member of the Percha shale is somewhat thicker than in adjacent areas.

The 17-foot Alamogordo member, thinnest in this region, consists of massive, hard, black, cherty limestone and forms a distinct scarp along the canyon walls. The Nunn member consists of soft, blue-gray, nodular crinoidal limestone beds overlain by interbedded soft, blue-gray crinoidal marls and nodular crinoidal limestone lenses. The basal beds have much black chert which is not normal for the member. A typical Nunn fauna collected from the marly slopes included: *Steganocrinus pentagonus*, *Cactocrinus* (?) cf. *C. coelatus*, *Amphoracrinus divergens*, *Actinocrinites rubra*, and several species of *Platycrinites*.

The Tierra Blanca member is massive, gray to black, very crinoidal, fairly even-bedded, cherty limestone. The upper portion does not carry the chert concentrations as is common in many exposures. Rocks of Kelly age appear to rest conformably on the upper surface of the Tierra Blanca over much of the area. In one place along the canyon wall a local red shaly zone between Tierra Blanca and Kelly rocks seems to be evidence of an unconformity.

The rocks tentatively assigned to the Kelly formation consist of massive, gray, crinoidal limestone with minor amounts of chert. The chert beds are distinctly smaller in size than those of the underlying Tierra Blanca beds. No fossils were collected from Kelly rocks.

Rocks of lower Pennsylvanian age rest on the Kelly with marked unconformity. A brown, sandy, basal chert conglomerate rests on an irregular solution surface on

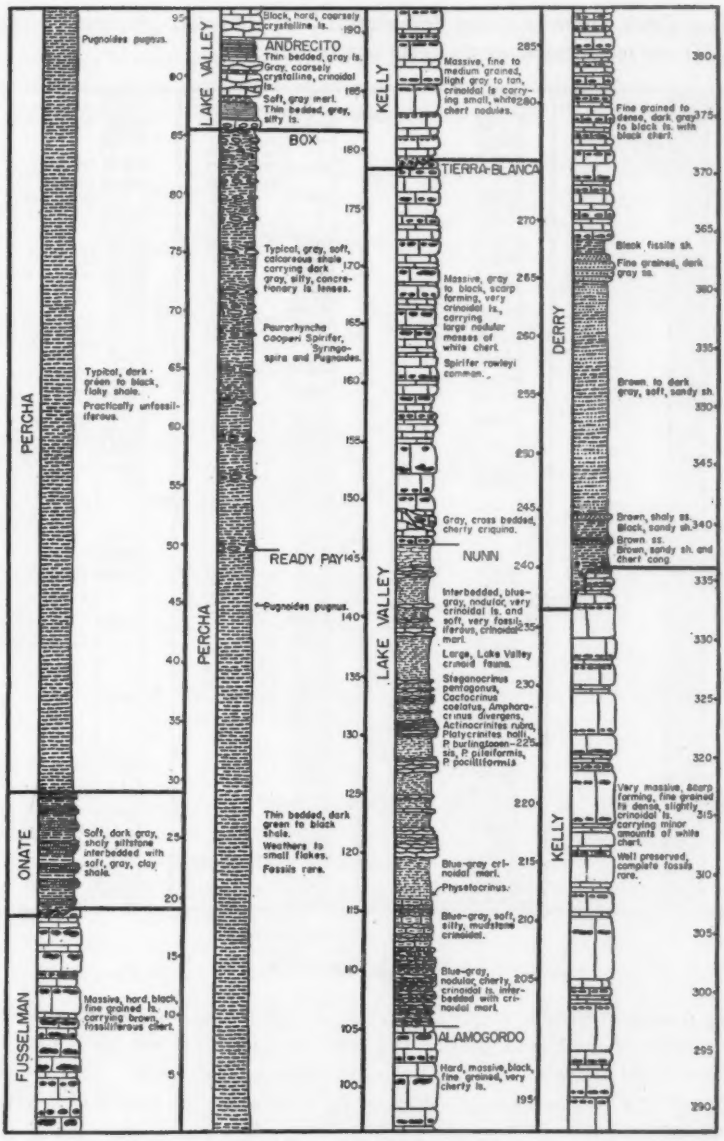
FUSSELMAN
ONATE
PERCHA
Massive, hard, black, fine grained ls. carrying brown, fossiliferous chert.
Soft, dark gray, shaly siltstone interbedded with soft, gray, clay shale.
Typical, dark green to black, flaky shale. Practically unfossiliferous.
Pugnoides pugnus.
LAKE VALLEY
PERCHA
Thin bedded, dark green to black shale. Weathers to small flakes. Fossils rare.
Pugnoides pugnus.
READY PAY
Typical, gray, soft, calcareous shale carrying dark gray, silty, concretionary ls. lenses.
Pourortyncha coopeni Spirifer, Syringospira and Pugnoides.
BOX
Soft, gray marl. Thin bedded, gray, silty ls.
ANDRECITO
Thin bedded, gray ls. Gray, coarsely crystalline, crinoidal ls.
Black, hard, coarsely crystalline ls.
KELLY
LAKE VALLEY
Blue-gray crinoidal marl.
Physetocrinus.
Blue-gray, soft, silty, mudstone crinoidal.
Blue-gray, nodular, cherty crinoidal ls. interbedded with crinoidal marl.
ALAMOGORDO
Hard, massive, black, fine grained, very cherty ls.
Massive, fine to medium grained, light gray to tan, crinoidal ls carrying small, white chert nodules.
TIERRA BLANCA
Massive, gray to black, scarp forming, very crinoidal ls., carrying large nodular masses of white chert.
Spirifer rowleyi common.
Gray, cross bedded, cherty crinoina.
NUNN
Interbedded, blue-gray, nodular, very crinoidal ls. and soft, very fossiliferous, crinoidal marl.
Large, Lake Valley crinoid fauna.
Steganocrinus pentagonus, Coctocrinus coelatus, Amphoracrinus divergens, Actinocrinites rubra, Platycrinites halli, P burlingtoaen-sis, P paleiformis, P pocilliformis
DERRY
KELLY
Fine grained to dense, dark gray to black ls. with black chert.
Black fissile sh.
Fine grained, dark gray ss.
Brown to dark gray, soft, sandy sh.
Brown, shaly ss.
Black, sandy sh.
Brown ss.
Brown, sandy sh. and chert cong.
Very massive, scarp forming, fine grained to dense, slightly crinoidal ls. carrying minor amounts of white chert.
Well preserved, complete fossils rare.

FIGURE 36.—*North Percha Creek section*

SW¼, Sec. 24, T 15 S, R 9 W.

top, and is overlain by 2 feet of red to brown, oxidized, sandy black shale carrying considerable carbonaceous material.

Hermosa section.—Mississippian rocks are excellently exposed along both walls of

Palomas Creek a short distance downstream from Hermosa. A complete section (Fig. 37) was measured along the north canyon wall.

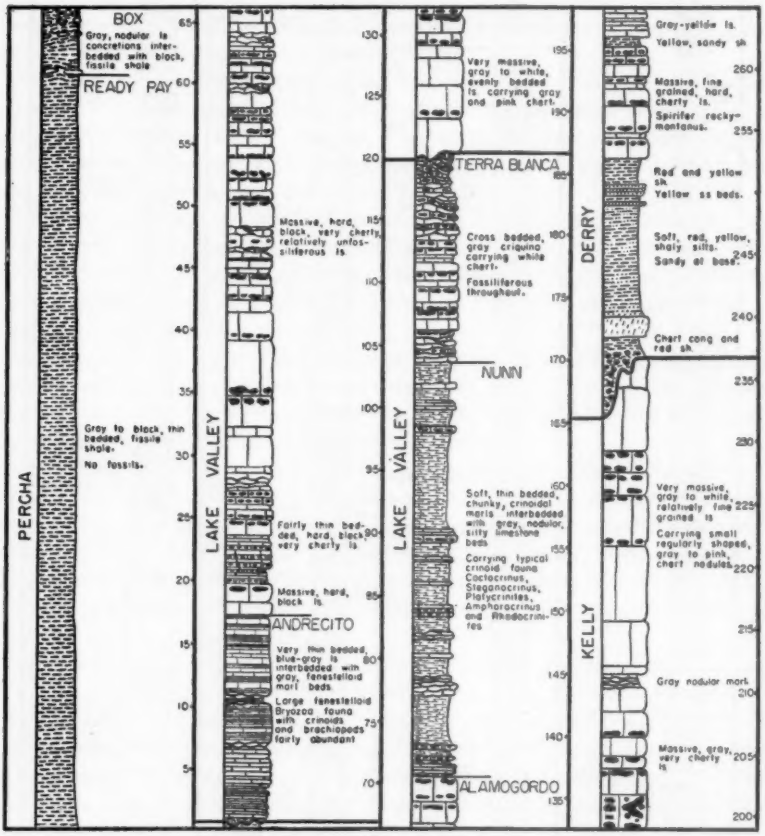
PERCHA
BOX
Gray, nodular ls concretions interbedded with black, fissile shale
READY PAY
Gray to black, thin bedded, fissile shale. No fossils.
LAKE VALLEY
Massive, hard, black, very cherty, relatively unfossiliferous ls
Fairly thin bedded, hard, black very cherty ls
Massive, hard, black ls
ANDRECITO
Very thin bedded, blue-gray ls interbedded with gray, fenestelloid marl beds
Large fenestelloid Bryozoa fauna with crinoids and brachiopods fairly abundant
LAKE VALLEY
Very massive, gray to white, evenly bedded ls carrying gray and pink chert
TERRA BLANCA
Cross bedded, gray crinoid carrying white chert. Fossiliferous throughout.
NUNN
Soft, thin bedded, chunky, crinoidal marls interbedded with gray, nodular, silty limestone beds
Carrying typical crinoid fauna Cactocrinus, Steganocrinus, Platycrinites, Amphoracrinus and Rhodocrinites
ALAMOGORDO
DERRY
KELLY
Gray-yellow ls
Yellow, sandy sh
Massive, fine grained, hard, cherty ls. Spirifer rockymontanus.
Red and yellow sh
Yellow ss beds
Soft, red, yellow, shaly silts. Sandy at base
Chert cong and red sh
Very massive, gray to white, relatively fine grained ls
Carrying small regularly shaped, gray to pink, chert nodules
Gray nodular marl
Massive, gray, very cherty ls

FIGURE 37.—*Hermosa section*

SW¼, Sec. 13, T 13 S, R 9 W.

The Andrecito member of the Lake Valley formation rests unconformably on the Box member of the Percha shale. The basal few inches are soft black shale often oxidized to red and with "phosphatic" concretions and fish teeth. This grades upward into very thin-bedded, soft, gray, marly limestones with masses of fenestelloid bryozoans.

The Alamogordo member, 57 feet thick, is sharply set apart from the underlying Andrecito by its massive bedding and as it usually forms an imposing escarpment. The massive, black, fine-grained, very cherty limestone beds of the former are poorly fossiliferous.

The Nunn member is soft, blue-gray marl and nodular, gray, crinoidal limestone. The percentage of shaly material is larger in this area than at the type section to the south. Typical Nunn crinoids occur here, such as *Steganocrinus pentagonus*, *Eucladocrinus pleuroviminus*, *Physetocrinus lobatus*, and *Cactocrinus* (?) cf. *C. multibrachiatus*.

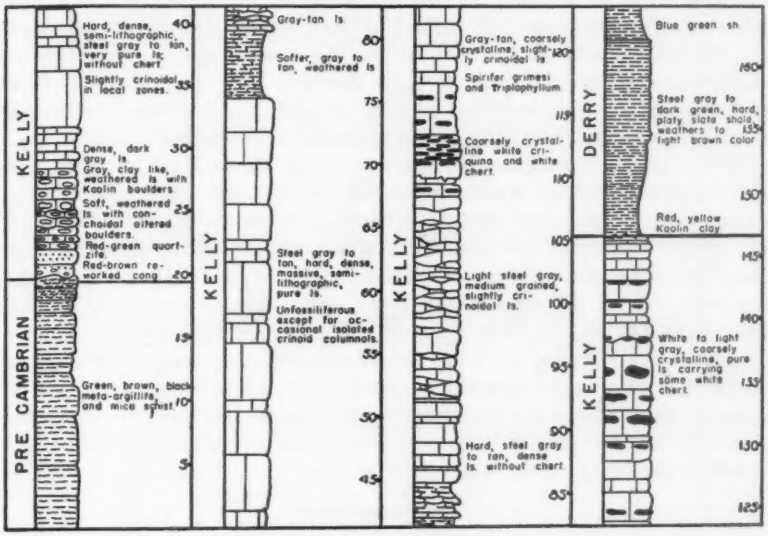
PRE CAMBRIAN
KELLY
Hard, dense, semi-lithographic, steel gray to tan, very pure ls; without chert
Slightly crinoidal in local zones.
Dense, dark gray ls
Gray, clay like, weathered ls with Kaolin boulders
Soft, weathered ls with conchoidal altered boulders.
Red-green quartzite.
Red-brown reworked cong
Green, brown, black meta-argillite, and mica schist
KELLY
Gray-tan ls.
Softer, gray to tan, weathered ls
Steel gray to tan, hard, dense, massive, semi-lithographic, pure ls.
Unfossiliferous except for occasional isolated crinoid columnals.
KELLY
Gray-tan, coarsely crystalline, slightly crinoidal ls
Spirifer grimesi and Triplophyllum
Coarsely crystalline white crinoina and white chert.
Light steel gray, medium grained, slightly crinoidal ls.
Hard, steel gray to tan, dense ls without chert.
DERRY
Blue green sh
Steel gray to dark green, hard, platy slate shale, weathers to light brown color
Red, yellow Kaolin clay
KELLY
White to light gray, coarsely crystalline, pure ls carrying some white chert.

FIGURE 38.—*Kelly section, Magdalena District*

NE¼, NE¼, Sec. 36, T 2 S, R 4 W.

The thinly developed Tierra Blanca member consists of 18 feet of gray, massive, nodular crinoidal limestone beds, with much white chert. Common Lake Valley fossils such as *Spirifer rowleyi* and *Athyris lamellosa* occur occasionally.

The Tierra Blanca is unconformably overlain by rocks referred tentatively to the Kelly formation. These are massive, gray to tan, moderately fine-grained limestone beds, 17 feet thick, that carry small amounts of cherts. As in the Silver City area, some of the cherts are pink. No fossils were recovered from these rocks in the Hermosa area. The top of the Tierra Blanca has considerable chert and appears to be slightly leached. The contact is sharp and without much indication of unconformity.

The Kelly is overlain with marked unconformity by Pennsylvanian rocks. Chert conglomerates mark the beds directly above the contact.

Kelly section.—The Mississippian rocks exposed in the Kelly area are extensively complicated by folding and faulting. In general they dip steeply to the northwest and strike northeast across the north end of the range at Kelly. The region is quite heavily covered with vegetation, and exposures are poor. Complete sections are available for study underground in the mines, and a complete section can be pieced together along the escarpment above the mining area (Fig. 38).

The Kelly formation rests directly on pre-Cambrian metamorphic rocks. The contact is sharply unconformable, and considerable amounts of reworked materials are present in the basal Mississippian. A thin quartzite bed occurs near the base, followed by a zone of soft, gray, weathered limestone filled with large, rounded, weathered, clay boulders. The main limestone body is broken into two parts on weathered slopes by a softer, gray to tan, thinly bedded limestone which retreats between the two limestone cliffs. The lower hard bed consists of very fine-grained, pure, semilithographic, tan to very light gray, massive limestone. Except for a few crinoid columnals, no fossils were found in this bed. The upper hard, cliff-forming bed consists of slightly more thinly bedded, light-gray to tan, fine-grained limestone containing some chert. One crinoidal bed occurs in the middle of this zone.

The base of this upper limestone is known as the "Silver Pipe" to the miners because it is just below the mineralized zone mined in the Kelly-Graphic Mine. On the surface it appears as a hard, very fine-grained, steel-gray limestone. Fossils, other than crinoid fragments, are rare. Several large brachiopods resembling *Spirifer grimesi* and a few corals closely resembling *Triplophyllum dalei* were observed, but none were collected. The Kelly formation is unconformably overlain by soft, flaky, Pennsylvanian shale. Because of the very soft shale exposures are poor.

The authors are placing the Kelly formation in the upper part of the Osage series because of its stratigraphic relations, but fossil evidence is not conclusive. The Kelly lithologic characteristics are so different from those of beds which we have referred tentatively to this formation in the Mimbres Range and Silver City area, that it is not certain that they are the same.

COOKS RANGE

Summary.—No rocks of Caballero age have been positively identified in the Cooks Range. The nodular limestone beds in the base of the Andrecito member in the Middle Cooks section resemble Caballero rocks lithologically, but the fauna indicates closer affinities with the Lake Valley formation. The Andrecito member reaches its maximum thickness of 270 feet in the Middle Cooks area (Fig. 39). The Alamogordo member is feebly developed except in the northern part of the range. The Nunn member consists of soft, gray, very shaly marls in which the normal nodular limestone lenses are not prominently developed. The Tierra Blanca consists of very cherty crinoidal limestone. No beds of Arcente or Dona Ana age have been found in the range. A thin development of cherty limestone beds in the northern and central portion of the range has been tentatively referred to the Kelly formation. No beds of Las Cruces, Rancheria, or Helms age have been found.

General description.—Mississippian rocks in this area dip generally south, causing them to rise highest above the valley floor in the extreme north end of the range. The rocks are excellently exposed in steep escarpments which face west, north, and east around the northern end of the range.

North Cooks Range section.—The measured section (Fig. 40) is located on the slope just above the mining area on the east side of the range near the north end. The Andrecito member of the Lake Valley formation rests unconformably on the Box member of the Percha shale. An oxidized zone with a thin sandy conglomerate marks

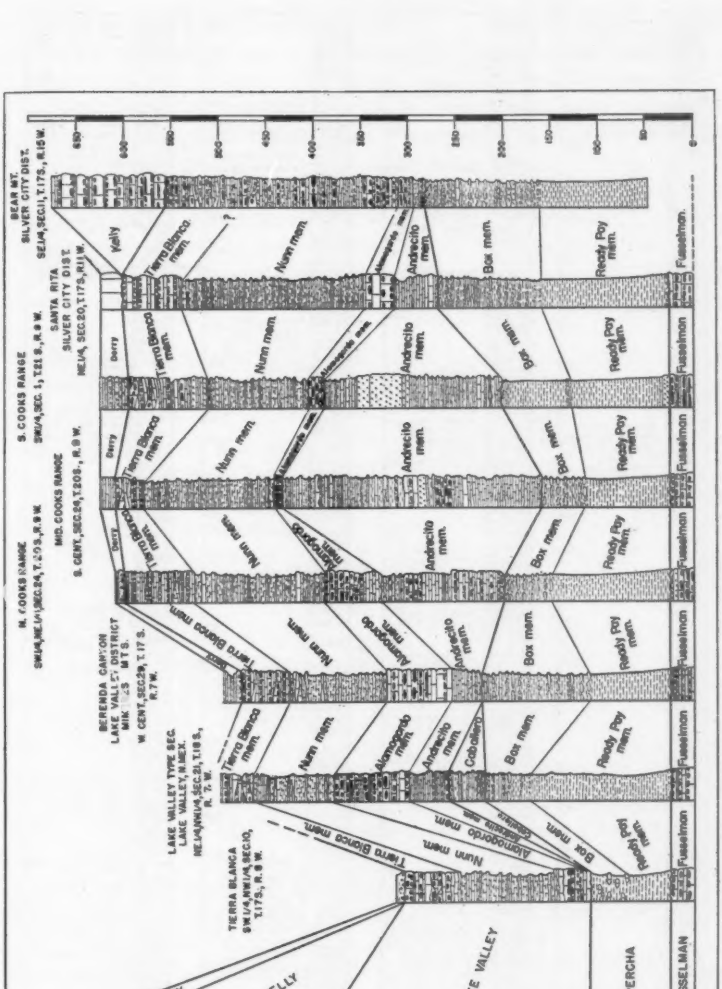

FIGURE 39.—*Correlation of sections—Lake Valley, Cooks and Silver City areas*

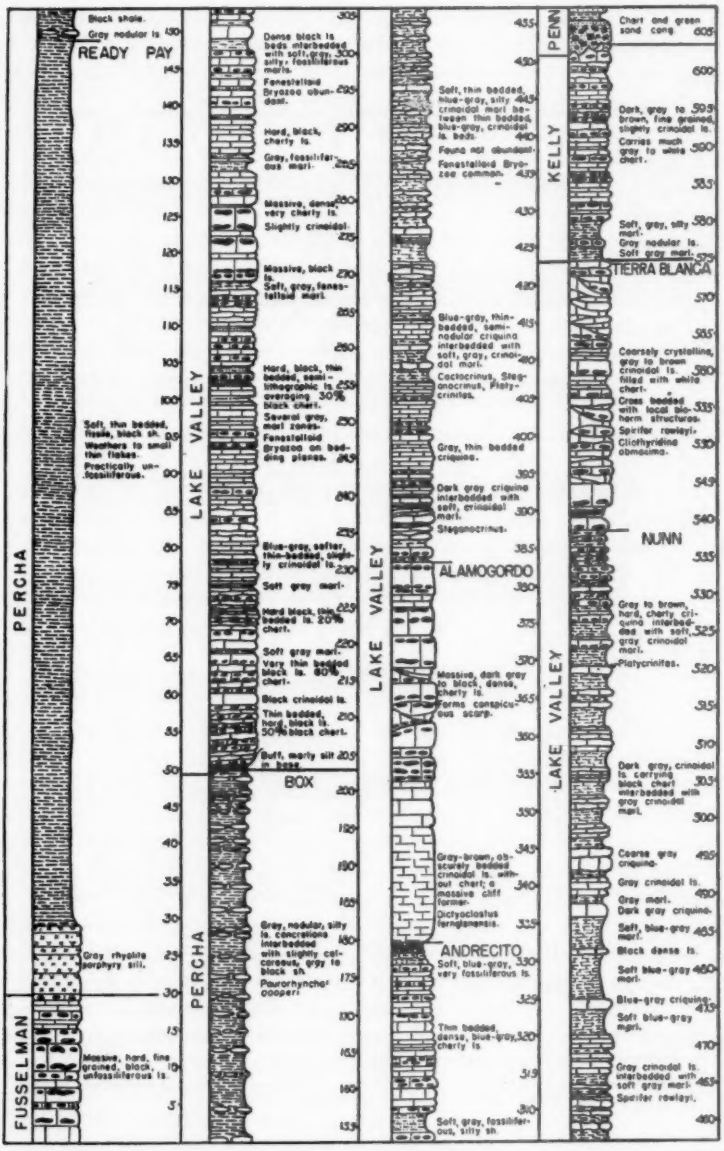
FUSSELMAN
PERCHA
LAKE VALLEY
PERCHA
LAKE VALLEY
PENN
KELLY
LAKE VALLEY
Black shale.
Gray nodular ls.
READY PAY
Soft, thin bedded, fissile, black sh.
Weathers to small thin flakes.
Practically unfossiliferous.
Gray rhyolite porphyry sill.
Massive, hard, fine grained, black unfossiliferous ls.
Dense black ls beds interbedded with soft gray, silty fossiliferous marls.
Fenestellaid Bryozoa abundant.
Hard, black, cherty ls.
Gray, fossiliferous marl.
Massive, dense, very cherty ls.
Slightly crinoidal.
Massive, black ls.
Soft, gray, fenestellaid marl.
Hard, black, thin bedded, semi-lithographic ls averaging 30% black chert.
Several gray marl zones.
Fenestellaid Bryozoa on bedding planes.
Blue-gray, softer, thin-bedded, slightly crinoidal ls.
Soft gray marl.
Hard black, thin bedded ls. 20% chert.
Soft gray marl.
Very thin bedded black ls. 80% chert.
Black crinoidal ls.
Thin bedded, hard, black ls. 50% black chert.
Buff, marly silt in base.
BOX
Gray, nodular, silty ls. concretions interbedded with slightly calcareous, gray to black sh.
Pourorhynchus cooperi
Soft, thin bedded, blue-gray, silty crinoidal marl between thin bedded, blue-gray, crinoidal ls. beds.
Fenestellaid Bryozoa common.
Blue-gray, thin-bedded, semi-nodular crinoina interbedded with soft, gray, crinoidal marl.
Cactocrinus, Stegnocrinus, Platycrinites.
Gray, thin bedded crinoina.
Dark gray crinoina interbedded with soft, crinoidal marl.
Stegnocrinus.
ALAMOGORDO
Massive, dark gray to black, dense, cherty ls.
Forms conspicuous escarp.
Gray-brown, obscurely bedded crinoidal ls. without chert; a massive cliff former.
Dictyoclostus farnhamensis.
ANDRECITO
Soft, blue-gray, very fossiliferous ls.
Thin bedded, dense, blue-gray, cherty ls.
Soft, gray, fossiliferous, silty sh.
Chert and green sand cong.
Dark, gray to brown, fine grained, slightly crinoidal ls.
Carries much gray to white chert.
Soft, gray, silty marl.
Gray nodular ls.
Soft gray marl.
TIERRA BLANCA
Coarsely crystalline, gray to brown crinoidal ls. filled with white chert.
Cross bedded with local bio-herm structures.
Spirifer rowleyi.
Cliothyridina obmaxima.
NUNN
Gray to brown, hard, cherty crinoina interbedded with soft, gray crinoidal marl.
Platycrinites.
Dark gray, crinoidal ls carrying black chert interbedded with gray crinoidal marl.
Coarse gray crinoina.
Gray crinoidal ls.
Gray marl.
Dark gray crinoina.
Soft, blue-gray marl.
Black dense ls.
Soft blue-gray marl.
Blue-gray crinoina.
Soft blue-gray marl.
Gray crinoidal ls interbedded with soft gray marl.
Spirifer rowleyi.

FIGURE 40.—*North Cooks Range section*

SW¼, NE¼, Sec. 24, T 20 S, R 9 W.

the contact. The Andrecito member, lithologically similar to correlative strata in the San Andres Range, consists predominantly of hard, black, fine-grained, relatively

thin-bedded, sparsely fossiliferous limestone with considerable chert. Part is somewhat nodular, particularly toward the base. The commonest fossils are fenestelloid bryozoans which often cover the bedding surfaces. *Spirifer louisianensis, Dictyoclostus fernglenensis, Athyris lamellosa,* and *Cyathoxonia arcuata* occur occasionally.

In the upper 30 feet of the Andrecito are several soft, gray, crinoidal marl members, lithologically not unlike the soft marls of the Nunn member. They are underlain by a hard cherty portion of the member, which gives the false impression that there are two beds which should be classed as belonging to the Alamogordo member. These soft crinoidal marls in the upper part contain fairly abundant fossils. *Spirifer louisianensis* and *Spirifer vernonensis* are most abundant. The crinoidal marls which would be expected to yield good crinoid faunas have to date yielded only species of *Platycrinites*.

The Alamogordo member, 50 feet thick, contains a very massive, slightly crinoidal bed at the base which is overlain by massive, black cherty limestone beds and forms a distinct cliff along the face of the mountain.

The Nunn member is excellently developed in the area and reaches a thickness of 155 feet. The soft, gray, crinoidal marls are more shaly than in the type Lake Valley area, but the crinoid faunas are poorly developed. A typical Nunn assemblage which includes *Steganocrinus pentagonus, Cactocrinus* (?) cf. *C. multibrachiatus, Amphoracrinus divergens,* and several species of *Platycrinites* occurs near the base. As in the type section area, the upper beds of the member become cherty and contain brown criquina layers.

The Nunn member grades upward into the Tierra Blanca member, which consists of 35 feet of hard, brown to gray, very cherty criquina.

The upper 30 feet of beds just beneath the Pennsylvanian are tentatively referred to the Kelly formation, although evidence for such correlation is not well substantiated. These rocks rest on the underlying Tierra Blanca with probable marked unconformity. A distinctly weathered contact is overlain by an oxidized clay. The upper layers have smoothly rounded white chert nodules similar to those found in the Kelly in the Silver City area. Except for crinoid fragments, the formation is without fossils.

Middle Cooks Range sections.—A very complete section of Mississippian rocks is available for study along the bed of a small creek which cuts into the east side of Cooks Range in the center of Section 24 (Fig. 41).

Here the Andrecito member rests unconformably on the Box member of the Percha shale. The Andrecito is unusual in containing a thick development of thin-bedded, nodular, noncherty, very fossiliferous limestones in the base. These beds, 95 feet thick, forming a massive cliff, apparently are stratigraphically older than strata in the base of the Andrecito a few miles to the north in the north end of the range. The Andrecito member is only 125 feet thick in the North Cooks Range section, while in this area it is 270 feet thick. As this section is only a few miles south of the North Cooks section, the surface on which the Lake Valley was laid down apparently had considerable relief. Because of their nodular nature, we first assumed that the beds were of Caballero age, but the presence of considerable chert and of common Andrecito fossils forced us to refer them to the Andrecito member. The surface of limestone slabs in the upper portion of this zone are covered by fenestelloid bryozoans.

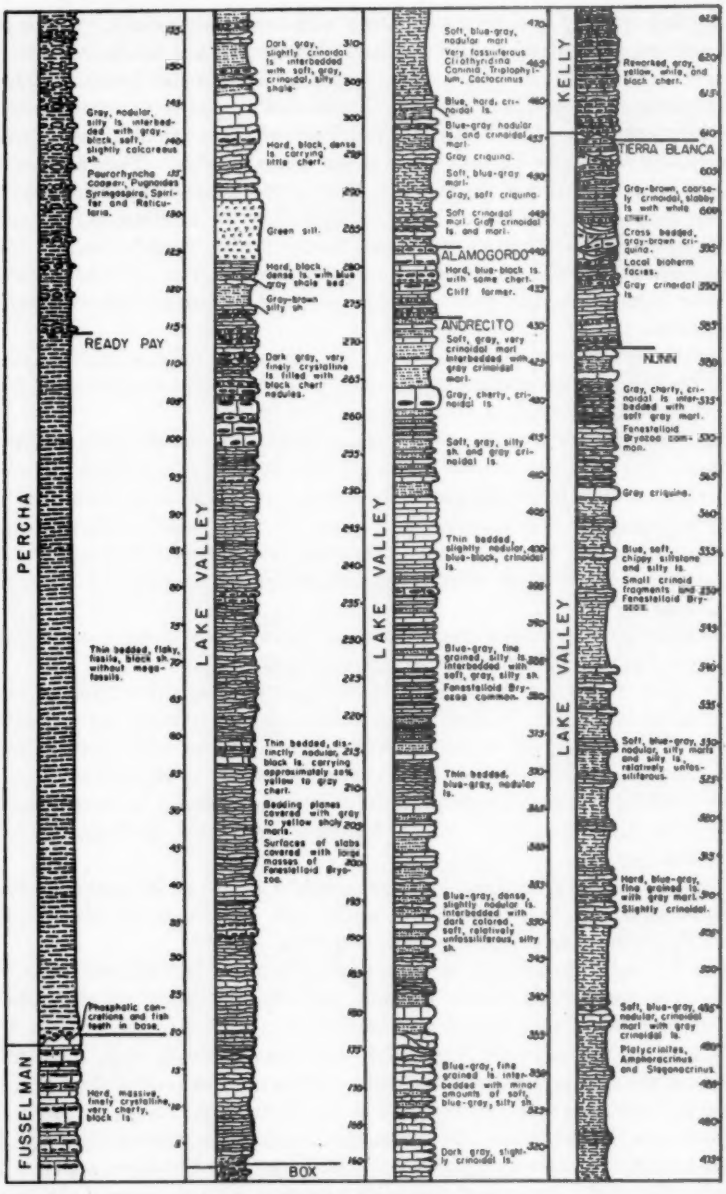
FUSSELMAN
PERCHA
LAKE VALLEY
LAKE VALLEY
LAKE VALLEY
KELLY
TIERRA BLANCA
NUNN
ALAMOGORDO
ANDRECITO
READY PAY
BOX
Gray, nodular, silty ls interbedded with gray-black, soft, slightly calcareous sh.
Pourorhyncha, Cooperi, Pugnoides, Syringospira, Spirifer and Reticularia.
Thin bedded, flaky, fissile, black sh without megafossils.
Phosphatic concretions and fish teeth in base.
Hard, massive, finely crystalline, very cherty, black ls
Dark gray, slightly crinoidal ls interbedded with soft, gray, crinoidal, silty shale.
Hard, black, dense ls carrying little chert.
Green sill.
Hard, black, dense ls with blue gray shale bed
Gray-brown silty sh
Dark gray, very finely crystalline ls filled with black chert nodules.
Thin bedded, distinctly nodular, black ls carrying approximately 50% yellow to gray chert.
Bedding planes covered with gray to yellow shaly marls.
Surfaces of slabs covered with large masses of Fenestelloid Bryozoa.
Soft, blue-gray, nodular marl
Very fossiliferous Clothyridina, Camnia, Triplophyllum, Cactocrinus
Blue, hard, crinoidal ls.
Blue-gray nodular ls and crinoidal marl
Gray crinoina.
Soft, blue-gray marl.
Gray, soft crinoina.
Soft crinoidal marl. Griff crinoidal ls and marl.
Hard, blue-black ls with some chert.
Cliff former.
Soft, gray, very crinoidal marl interbedded with gray crinoidal marl.
Gray, cherty, crinoidal ls
Soft, gray, silty sh. and gray crinoidal ls.
Thin bedded, slightly nodular, blue-black, crinoidal ls.
Blue-gray, fine grained, silty ls interbedded with soft, gray, silty sh.
Fenestelloid Bryozoa common.
Thin bedded, blue-gray, nodular ls.
Blue-gray, dense, slightly nodular ls interbedded with dark colored, soft, relatively unfossiliferous, silty sh.
Blue-gray, fine grained ls interbedded with minor amounts of soft, blue-gray, silty sh.
Dark gray, slightly crinoidal ls.
Reworked, gray, yellow, white, and black chert.
Gray-brown, coarsely crinoidal, slabby ls with white chert.
Cross bedded, gray-brown crinoina.
Local bioherm facies.
Gray crinoidal ls
Gray, cherty, crinoidal ls interbedded with soft gray marl.
Fenestelloid Bryozoa common.
Gray crinoina.
Blue, soft, chippy siltstone and silty ls.
Small crinoid fragments and Fenestelloid Bryozoa.
Soft, blue-gray, nodular, silty marls and silty ls, relatively unfossiliferous.
Hard, blue-gray, fine grained ls with gray marl. Slightly crinoidal.
Soft, blue-gray, nodular, crinoidal marl with gray crinoidal ls.
Platycrinites, Amphoracrinus and Stegonocrinus.

FIGURE 41.—*Middle Cooks Range section*

S Center, Sec. 24, T 20 S, R 9 W.

Cyathaxonia arcuata, a small species of *Zaphrentis*, *Rhipidomella missouriensis*, *Spirifer louisianensis*, *Athyris lamellosa*, and *Dictyoclostus fernglenensis* occur sparingly in the upper portion. The remainder of the Andrecito member is similar to that of the North Cooks section, except that more soft marl beds are included in the upper portion.

The Alamogordo member does not have the brown beds of criquina at its base. This is the thinnest section referable to the Alamogordo member found in southwestern New Mexico, 9 feet thick.

The Nunn member is typically developed with unusually large amounts of soft, slightly crinoidal, blue-gray marl. Much of the section appears as soft shale slopes. A typical Nunn crinoid fauna can be collected, but in general the member is poorly fossiliferous. *Cactocrinus* (?), *Steganocrinus*, *Amphoracrinus*, *Platycrinites*, *Physetocrinus*, and *Rhodocrinites* have been collected from these slopes.

The Tierra Blanca member consists of 25 feet of hard, brown, very cherty criquina that exhibits cross-bedding related to local bioherm facies.

Fifteen feet of yellow to brown reworked (?) chert interbedded with gray to brown limestone lies unconformably on the Tierra Blanca member at the top of the section and is tentatively referred to the Kelly formation.

South Cooks Range section.—Mississippian rocks are well exposed along the east side of the Cooks Range until they plunge beneath the valley floor about midway between the north and south ends of the range. The South Cooks section (Fig. 42) was measured along the walls of a small creek that cuts into the east side of the range in Section 1.

The Andrecito member rests unconformably on a thin remnant of the Box member of the Percha formation. The former is approximately 85 feet thick, but 55 feet of igneous rock is included. The Andrecito member is much thinner in this area. The nodular limestone beds, which lie at the base of the Andrecito section in the Middle Cooks area, are only partly developed here. The upper portion of the member consists of hard, fine-grained, black, cherty, poorly fossiliferous limestone beds and contains soft, blue-gray, shaly marls just below the Alamogordo member, as it does throughout the Cooks Mountains area.

The Alamogordo member is thin, 13 feet thick, but forms a typically massive cliff along the mountain front. It contains characteristically rounded, concentrically banded chert nodules.

The Nunn member is soft, blue-gray marl with several harder conspicuous limestone beds. It is approximately 140 feet thick which is almost identical with its thickness in the Middle Cooks area. Typical Nunn fossils such as *Cactocrinus* (?) *Rhodocrinites*, *Steganocrinus*, *Spirifer rowleyi*, and *Dictyoclostus fernglenensis* have been collected.

The Tierra Blanca member consists of massive, gray to brown, cherty limestone that forms a steep cliff. In this area it is slightly thicker than in either the North or Middle Cooks sections. No beds of Kelly age are present, because the Tierra Blanca member is overlain directly by conglomerates of Pennsylvanian age.

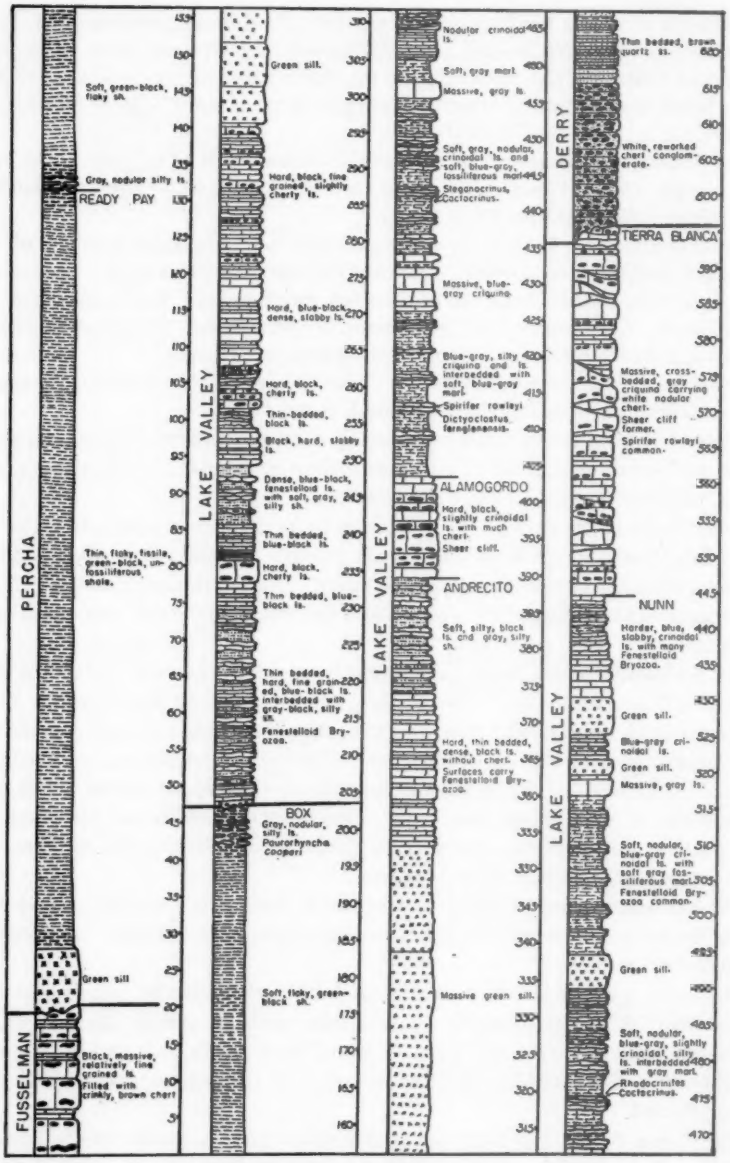
PERCHA
FUSSELMAN
Soft, green-black, flaky sh.
Gray, nodular silty ls.
READY PAY
Thin, flaky, fissile, green-black, unfossiliferous shale.
Green sill
Black, massive, relatively fine grained ls. Filled with crinkly, brown chert
LAKE VALLEY
Green sill.
Hard, black, fine grained, slightly cherty ls.
Hard, blue-black, dense, slabby ls.
Hard, black, cherty ls.
Thin-bedded, black ls.
Black, hard, slabby ls.
Dense, blue-black, fenestelloid ls. with soft, gray, silty sh.
Thin bedded, blue-black ls.
Hard, black, cherty ls.
Thin bedded, blue-black ls.
Thin bedded, hard, fine grained, blue-black ls. interbedded with gray-black, silty sh.
Fenestelloid Bryozoa.
BOX
Gray, nodular, silty ls. Pourarhyncha cooperi
Soft, flaky, green-black sh.
LAKE VALLEY
Nodular crinoidal ls.
Soft, gray marl.
Massive, gray ls.
Soft, gray, nodular, crinoidal ls. and soft, blue-gray, fossiliferous marl
Steganocrinus, Cactocrinus.
Massive, blue-gray crinoina.
Blue-gray, silty crinoina and ls. interbedded with soft, blue-gray marl.
Spirifer rowleyi
Dictyoclostus farnglenensis.
ALAMOGORDO
Hard, black, slightly crinoidal ls. with much chert.
Sheer cliff.
ANDRECITO
Soft, silty, black ls. and gray, silty sh.
Hard, thin bedded, dense, black ls. without chert. Surfaces carry Fenestelloid Bryozoa.
Massive green sill.
LAKE VALLEY
DERRY
Thin bedded, brown quartz ss.
White, reworked chert conglomerate.
TIERRA BLANCA
Massive, cross-bedded, gray crinoina carrying white nodular chert. Sheer cliff former. Spirifer rowleyi common.
NUNN
Harder, blue, slabby, crinoidal ls. with many Fenestelloid Bryozoa.
Green sill.
Blue-gray crinoidal ls.
Green sill.
Massive, gray ls.
Soft, nodular, blue-gray crinoidal ls. with soft gray fossiliferous marl. Fenestelloid Bryozoa common.
Green sill.
Soft, nodular, blue-gray, slightly crinoidal, silty ls. interbedded with gray marl. Rhadocrinites Cactocrinus.

FIGURE 42.—*South Cooks Range section*

SW¼, Sec. 1, T 21 S, R 9 W.

SILVER CITY AREA

Summary.—The Mississippian rocks rest unconformably on the Box member of the Percha shale in the Silver City area. The Andrecito member is thin in the area and lithologically resembles the Andrecito member in the Lake Valley area. The Alamogordo member is typically developed in the Santa Rita District. In the Bear Mountain the Nunn and Tierra Blanca members have been entirely replaced by cherty limestone not unlike that of the underlying Alamogordo member (Fig. 39). Lighter-gray, massive, slightly cherty limestone beds referred tentatively to the Kelly formation overlie the Lake Valley cherty limestone beds. From a distance Bear Mountain has the appearance of a large bioherm structure similar to the ones studied in the Sacramento Mountains. Because the area is badly covered with vegetation the lateral slopes are not exposed. We believe Nunn and Tierra Blanca rocks may yet be found in the vicinity of Bear Mountain.

General description.—Mississippian rocks constitute a conspicuous part of the hills in the Silver City area. They also form the host rock for many of the mineral deposits of the area.

Best exposures occur along the northeastward-facing scarp that trends southeastward through Georgetown a few miles east of the Fierro, Hanover and Santa Rita mining districts. Here Ordovician and Silurian rocks have been brought to the surface along the base of a fault block that is capped by Mississippian strata. The rocks dip southwestward from this fault zone to plunge beneath older sediments in the vicinity of Fort Bayard. Excellent sections can be studied at numerous intervals all along the northeast face of this scarp.

Santa Rita section.—The Santa Rita Section (Fig. 43), measured along the southern end of this scarp, lies along the north side of the Santa Rita-Hillsboro highway a few miles east of Santa Rita.

The Andrecito member of the Lake Valley formation rests unconformably on the Box member of the Percha formation. No rocks of Caballero age have been found in this area. The Andrecito member consists of very thin-bedded, gray, very fossiliferous limestone beds. In the basal part the thin limestone layers are interbedded with soft fossiliferous marls. The surfaces of slabs are covered with many fenestelloid bryozoans. The member becomes more massive toward the top and is much thinner in this area than in the Cooks Range to the southeast.

The typically developed Alamogordo member consists of an imposing scarp of massive, black, fine-grained, poorly fossiliferous, cherty limestone approximately 42 feet thick. The nodular black and white concentrically-banded chert bed that commonly marks the Alamogordo member is present.

The Nunn member is typical lithologically but is remarkably free of fossils though in most areas where thick developments of soft, blue-gray marls occur, excellent and abundant fossils occur. This section resembles the soft, poorly fossiliferous development of the Nunn member in the Cooks Range. In the Santa Rita area, the Nunn member consists of approximately 195 feet of soft blue-gray marl interbedded with thin-bedded, nodular, crinoidal limestone. A few specimens of *Dictyoclostus fernglenensis*, *Athyris lamellosa*, *Spirifer rowleyi*, and *Steganocrinus pentagonus* have been

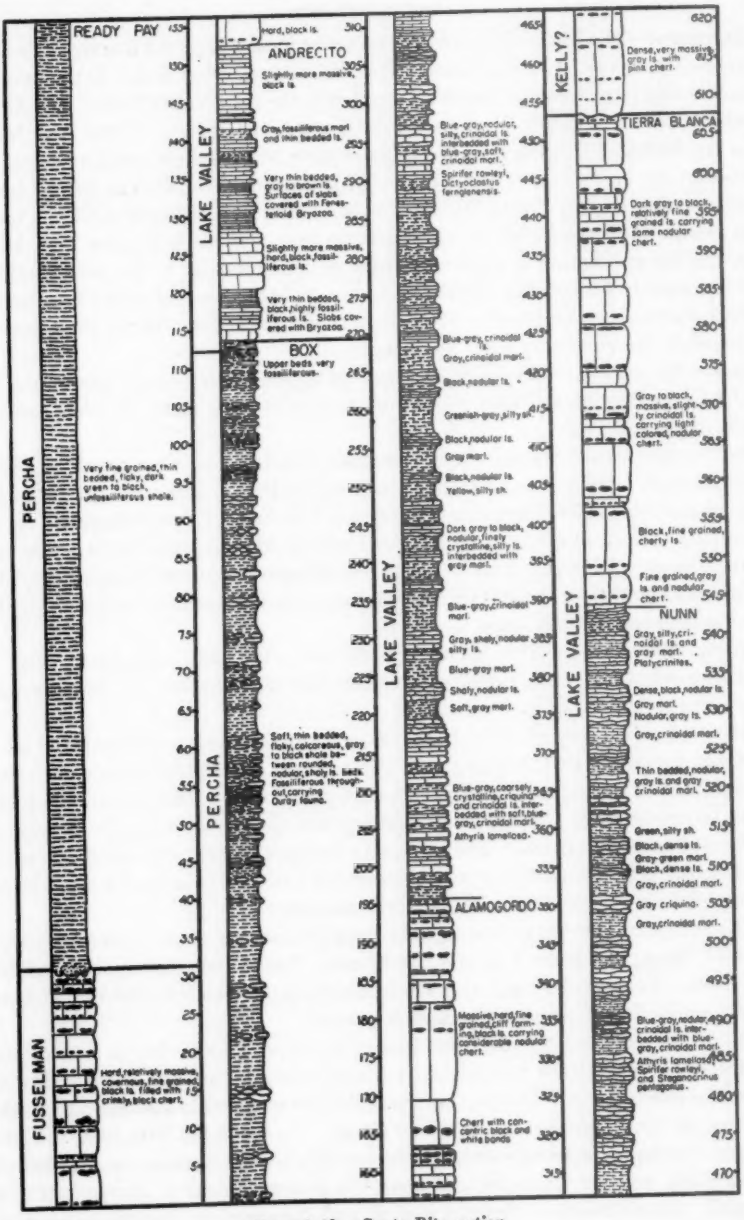
FUSSELMAN
PERCHA
READY PAY
Very fine grained, thin bedded, flaky, dark green to black, unfossiliferous shale.
Hard, relatively massive, cavernous, fine grained, black ls. filled with brown, oolitic, black chert.
LAKE VALLEY
PERCHA
Hard, black ls.
ANDRECITO
Slightly more massive, black ls.
Gray, fossiliferous marl and thin bedded ls.
Very thin bedded, gray to brown ls. Surfaces of slabs covered with Fenestelloid Bryozoa.
Slightly more massive, hard, black, fossiliferous ls.
Very thin bedded, black, highly fossiliferous ls. Slabs covered with Bryozoa.
BOX
Upper beds very fossiliferous.
Soft, thin bedded, flaky, calcareous, gray to black shale between rounded, nodular, shaly ls. beds. Fossiliferous throughout, carrying Ouray fauna.
LAKE VALLEY
Blue-gray, nodular, silty, crinoidal ls. interbedded with blue-gray, soft, crinoidal marl.
Spirifer rowleyi, Dictyoclostus ferrigeneusis.
Blue-gray, crinoidal ls.
Gray, crinoidal marl.
Black, nodular ls.
Greenish-gray, silty sh.
Black, nodular ls.
Gray marl.
Black, nodular ls.
Yellow, silty sh.
Dark gray to black, nodular, finely crystalline, silty ls. interbedded with gray marl.
Blue-gray, crinoidal marl.
Gray, shaly, nodular silty ls.
Blue-gray marl.
Shaly, nodular ls.
Soft, gray marl.
Blue-gray, coarsely crystalline, crinoidal and crinoidal ls. interbedded with soft, blue-gray, crinoidal marl. Athyris lamellosa.
ALAMOGORDO
Massive, hard, fine grained, cliff forming, black ls. carrying considerable nodular chert.
Chert with concentric black and white bands
KELLY?
LAKE VALLEY
Dense, very massive, gray ls. with pink chert.
TIERRA BLANCA
Dark gray to black, relatively fine grained ls. carrying some nodular chert.
Gray to black, massive, slightly crinoidal ls. carrying light colored, nodular chert.
Black, fine grained, cherty ls.
Fine grained, gray ls. and nodular chert.
NUNN
Gray, silty, crinoidal ls. and gray marl. Platycrinites.
Dense, black, nodular ls.
Gray marl.
Nodular, gray ls.
Gray, crinoidal marl.
Thin bedded, nodular, gray ls. and gray crinoidal marl.
Green, silty sh.
Black, dense ls.
Gray-green marl
Black, dense ls.
Gray, crinoidal marl.
Gray crinoidal marl.
Gray, crinoidal marl.
Blue-gray, nodular crinoidal ls. interbedded with blue-gray, crinoidal marl. Athyris lamellosa, Spirifer rowleyi, and Stegnocrinus pentagonius.

FIGURE 43.—*Santa Rita section*

NE¼, Sec. 20, T 17 S, R 11 W.

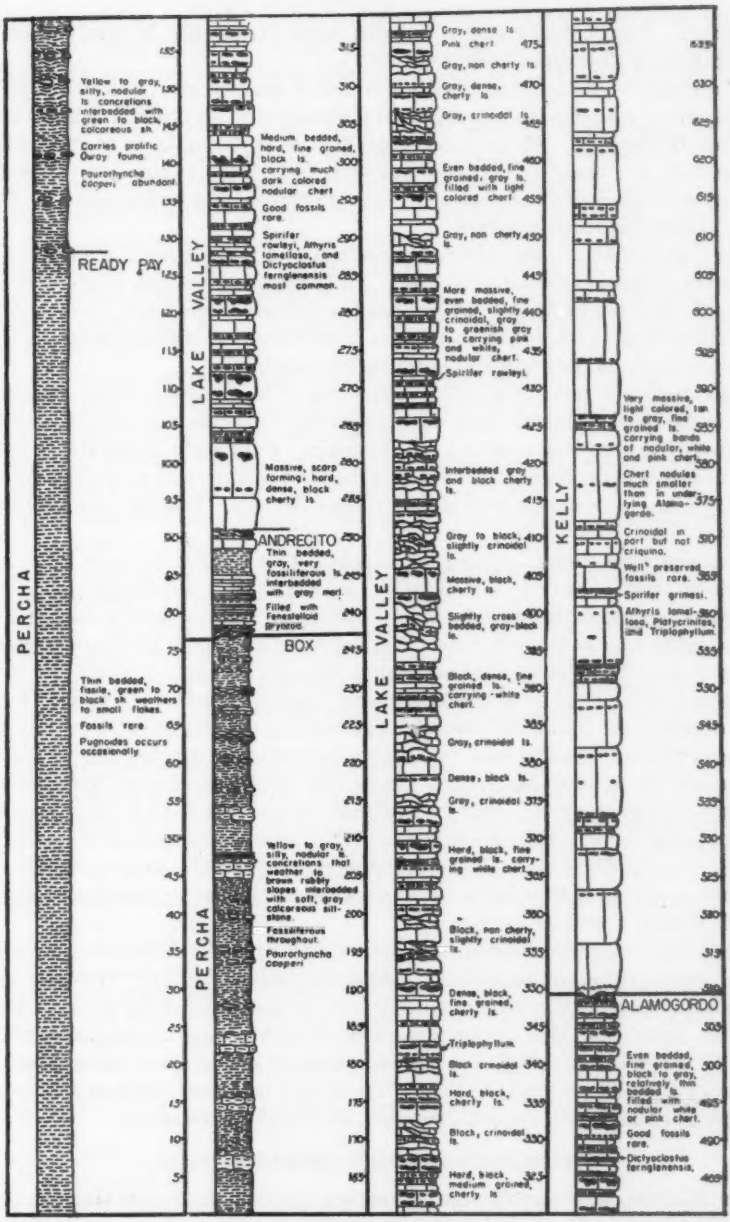
PERCHA
Yellow to gray, silty, nodular ls. concretions interbedded with green to black calcareous sh.
Carries prolific Ouray fauna
Pourorthyncha cooperi abundant
READY PAY
Thin bedded, fissile, green to black sh. weathers to small flakes.
Fossils rare
Pugnodes occurs occasionally
LAKE VALLEY
Medium bedded, hard, fine grained, black ls. carrying much dark colored nodular chert
Good fossils rare.
Spirifer rowleyi, Athyris lamellosa, and Dictyoclostus farnglanensis most common.
Massive, scarp forming, hard, dense, black cherty ls.
ANDRECITO
Thin bedded, gray, very fossiliferous ls. interbedded with gray marl
Filled with Fenestelloid Bryozoa.
BOX
Yellow to gray, silty, nodular ls. concretions that weather to brown rubbly slopes interbedded with soft, gray calcareous siltstone
Fossiliferous throughout
Pourorthyncha cooperi
PERCHA
LAKE VALLEY
Gray, dense ls
Pink chert
Gray, non cherty ls
Gray, dense, cherty ls
Gray, crinoidal ls
Even bedded, fine grained, gray ls. filled with light colored chert
Gray, non cherty ls.
More massive, even bedded, fine grained, slightly crinoidal, gray to greenish gray ls carrying pink and white, nodular chert.
Spirifer rowleyi.
Interbedded gray and black cherty ls.
Gray to black, slightly crinoidal ls.
Massive, black, cherty ls.
Slightly cross bedded, gray-black ls.
Black, dense, fine grained ls. carrying white chert.
Gray, crinoidal ls.
Dense, black ls.
Gray, crinoidal ls.
Hard, black, fine grained ls carrying white chert.
Black, non cherty, slightly crinoidal ls.
Dense, black, fine grained, cherty ls.
Triplophyllum
Black crinoidal ls.
Hard, black, cherty ls.
Black, crinoidal ls.
Hard, black, medium grained, cherty ls
KELLY
Very massive, light colored, tan to gray, fine grained ls carrying bands of nodular, white and pink chert
Chert nodules much smaller than in underlying Alamogordo
Crinoidal in part but not criquina.
Well preserved fossils rare.
Spirifer grimesi.
Athyris lamellosa, Platycrinites, and Triplophyllum.
ALAMOGORDO
Even bedded, fine grained, black to gray, relatively thin bedded ls. filled with nodular white or pink chert.
Good fossils rare.
Dictyoclostus farnglanensis.

FIGURE 44.—*Bear Mountain section*

SE¼, Sec. 11, T 17 S, R 15 W.

collected. Fragmentary crinoidal material occurs in profusion in some parts of the member, but well-preserved fossils are rare.

The Tierra Blanca member consists of 63 feet of massive, gray, crinoidal limestone having minor amounts of white chert but distinctly less chert than is common to the sections farther east. Much of the upper portion is dark-gray to black limestone rather than the usual light-colored limestone beds that are common to the east. Specimens of *Dictyoclostus fernglenensis* and *Spirifer rowleyi* were found only occasionally. Other fossils are very rare.

The Tierra Blanca is unconformably overlain by a thin sequence of massive, gray limestone ledges containing pink chert. Only the lower portion of this section is exposed along the highway. A low, rounded hillside covered with chert indicates that the section is probably much thicker. Gray limestone beds overlying the Tierra Blanca are referred provisionally to the Kelly formation.

Bear Mountain section.—Excellent exposures of Mississippian rocks can also be seen in the southwestward-facing escarpment that runs from the southwest suburbs of Silver City northwestward to Bear Mountain. Over much of this area it is difficult to measure complete sections because the Mississippian rocks cap the scarps and usually crop out down the back slope for some distance. Best exposures are found on Bear Mountain (Fig. 44).

The Andrecito member resting unconformably on the Percha shale, is typically developed, consisting of 15 feet of soft, thin-bedded, very fossiliferous, gray, shaly fossilierous, gray, shaly limestone beds. The black, massive, cherty Alamogordo, a scarp maker, rests on the Andrecito. Typical Nunn and Tierra Blanca sediments are not present. The Alamogordo member is followed by approximately 215 feet of medium-bedded, black to gray-black, cherty, slightly crinoidal limestone. Part of this section is nodular and exhibits the cross-bedding that suggests the conglomerate and crinoidal sandstone facies of the biohermal structures as developed in the northern end of the Sacramento Mountains. In no part of the Sacramento bioherm structures, however, does chert occur in the abundance found in this section. Fossils are rare; *Spirifer rowleyi*, *Athyris lamellosa*, and *Dictyoclostus fernglenensis* were collected. As the Nunn and Tierra Blanca members are typically developed a short distance to the east in the Santa Rita district this section may represent some part of a bioherm, possibly located within Bear Mountain.

The Lake Valley formation is overlain by a thick sequence of massive, gray to tan, fine-grained to dense limestone beds that are only slightly cherty. The chert occurs in small, rounded nodular bands and is pink in the lower part of the section. Fossils are rare, but one bed near the top of the section contains large brachiopods similar to *Spirifer grimesi*, and *Athyris lemellosa*, a species of *Platycrinites*, and a large coral probably referable to *Triplophyllum*. These beds have been referred to the Kelly formation because they are lithologically very like that division.

CONCLUSIONS AND RECOMMENDATIONS

The Mississippian rocks of southwestern New Mexico contain abundant, excellently preserved fossils. Study of these fossils revealed that a very large percentage of the species are new. The true significance of the New Mexico Mississippian fossils will

be apparent only when careful comparison is made with the faunas from the central part of the United States. The authors, jointly and separately, are engaged in studies of the extensive crinoid and brachiopod collections from the Mississippian rocks of New Mexico.

The Mississippian rocks in many areas of southwestern New Mexico contain anomolous structures described variously as "crinoid reefs" or "bioherms." Excellent developments of biohermal facies, exposed in the northern part of the Sacramento Mountains, afford extensive data concerning stratigraphic relationships, faunal distribution, lithologic characteristics and factors of sedimentation. These structures have been under investigation by the junior author for several months. It is believed that the results of this investigation will throw light on the problems of faunal distribution, paleoecology, facies change and factors controlling the classification of stratigraphic units.

The writers were confronted with numerous local problems quite beyond the scope of this stratigraphic study. It is our desire to present a list of significant problems, worthy of future investigation by other workers:

1. Study of the Sierra Caballo Mountains, Mud Springs Mountains, and the Robellero Mountains to ascertain why Mississippian rocks are absent.
2. Detailed study of the relations of the Lake Valley formation to the Kelly formation in the northern part of the Mimbres Range.
3. Study of the details of the marginal overlap of Mississippian rocks in the Peloncillo and Little Hatchet Mountains of New Mexico.
4. Study of the facies changes of the various Mississippian units from the south end of the Franklin to the north end of the San Andres Mountains.
5. Study of the unconformable relationships of Mississippian rocks with the underlying strata and the overlying Pennsylvanian rocks in the southwestern part of New Mexico.
6. Geologic mapping in the Mimbres Range.
7. Careful study of the reworked Mississippian cherts in the basal Pennsylvanian strata in an attempt to throw light on post-Mississippian pre-Pennsylvanian orogeny.

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GEOLOGIC MAP
OF THE
SIERRA DE LOS MUERTOS AREA
COAHUILA AND NUEVO LEON, MEXICO

BY WILLIAM E. HUMPHREY

SCALE

0 1 MILES 2 3

0 1 KILOMETERS 2 3

LEGEND

SEDIMENTARY ROCKS

UPPER CRETACEOUS RECENT

- Qa — ALLUVIUM
- Kp — PARRAS SHALE
- Ki — INDIDURA FORMATION
- Kc — CUESTA DEL CURA FORMATION

LOWER CRETACEOUS

- Ka — AURORA LIMESTONE
- Klp — LA PEÑA FORMATION
- Kcu — CUPIDO FORMATION
- Kt — TARAISES FORMATION
- Kl — LOWER CRETACEOUS UNDIFFERENTIATED

UPPER JURASSIC

- Jlc — LA CASITA FORMATION
- Jz — ZULOAGA FORMATION
- Ju — UPPER JURASSIC UNDIFFERENTIATED

SYMBOLS

- AXIS OF ANTICLINE
- AXIS OF OVERTURNED ANTICLINE
- AXIS OF SYNCLINE
- FAULT
- INFERRED FAULT
- THRUST FAULT (HACHURES ON OVERTHRUST SIDE)
- FORMATIONAL BOUNDARY
- INFERRED FORMATIONAL BOUNDARY
- STRIKE AND DIP
- STRIKE AND DIP-OVERTURNED STRATA
- MINE
- FOSSIL LOCALITY

SIERRA DE LOS MUERTOS
SIERRA DE LAS BOQUILLAS DE SANTO TORIBIO
SIERRA DEL CAPORAL
SIERRA DE LOS PLACERES
SIERRA DE LA CLAVELLINAS
CERRO DE ENMEDIO
MESA DE SAN ANTONIO
CAÑON DEL MORRO
CAÑON DE LAS MARAVILLAS
MUERTOS ANTICLINE
SAN BLAS ANTICLINE
CALLE SYNCLINE
CARRETERA 402
NACIONALES DE MEXICO
CASA BLANCA
TO MONTERREY
TO SALTILLO
POLICIA NACIONAL
HIGUERAS
OJO CALIENTE
SAN GREGORIO
LOS BAÑOS
RINCON DE SAN GREGORIO
RINCON DE LAS BOQUILLAS
RINCON DE BOTRERITOS
PUERTO DE LAS PALOMAS
CAÑON DE LAS PALOMAS
CAÑON DE LA MARAVILLA
CAÑON DE SALTILLOS
CAÑON DE LOS PLACERES
CAÑON DEL BORRITO LOBO
TANQUE DE LAS COLONIAS
TANQUE JAGUEY
EL ENCINO
LA PALOMA
LOS BARREROS
CERRITO DEL MUERTO
SAN JOSÉ DE ANUNCIOS
N

GEOLOGIC MAP
OF THE
SIERRA DE LOS MUERTOS AREA
COAHUILA AND NUEVO LEON, MEXICO

BY WILLIAM E. HUMPHREY

SCALE

MILES 0 1 2 3

KILOMETERS 0 1 2 3

SYMBOLS

- AXIS OF ANTICLINE
- AXIS OF OVERTURNED ANTICLINE
- AXIS OF SYNCLINE
- FAULT
- INFERRED FAULT
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- FORMATIONAL BOUNDARY
- INFERRED FORMATIONAL BOUNDARY
- STRIKE AND DIP
- STRIKE AND DIP-OVERTURNED STRATA
- MINE
- FOSSIL LOCALITY

CASA BLANCA
TO MONTERREY
NACIONALES DE MEXICO
HIGUERAS
POLICIA NACIONAL
CARRETERA 402
NUEVO LEON
COAHUILA
CAÑON DE LOS MUERTOS
SIERRA DE LOS MUERTOS
CAÑON DEL MORRO
SIERRA DEL MORRO
SIERRA DE LA CALLE
CAÑON DE SAN BLAS
SIERRA DE SAN BLAS
SIERRA DE LOS PLACERES
LOS MUERTOS ANTICLINE
CALLE SYNCLINE
SAN BLAS ANTICLINE
EL ENCINO
LA PALOMA
LOS BARREROS
OJO CALIENTE
GREGORIO
LOS BAÑOS
RINCON DE SAN GREGORIO
MUERTOS ANTICLINE
SIERRA DEL CAPORAL
RINCON DE POTRERITOS
PUERTO LAS PALOMAS
GYPSUM CAÑON DE LAS PALOMAS
CAÑON DE LA CANDELA
CAÑON DE SALTILLOS
MESA DE SAN ANTONIO
TANQUE DE LAS COLONIAS
CAÑON DE LOS PLACERES
CERRO DE ENMEDIO
LA CUESTA
CERRITO DEL MUERTO
SIERRA DE LAS CLAVELLINAS
CLAVELLINAS ANTICLINE
TANQUE JAQUEY
SAN JOSÉ DE ANUNCIOS
CAÑON DE LA ESCALERA
CAÑON DE LAS MARAVILLAS
CERRITO DEL JARDIN
LAS NAVAJAS

GEOLOGIC MAP, SIERRA DE LOS MUERTOS AREA, MEXICO

GEOLOGIC MAP, SIERRA DE LOS MUERTOS AREA, MEXICO

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GEOLOGY OF THE SIERRA DE LOS MUERTOS AREA, MEXICO

(WITH DESCRIPTIONS OF APTIAN CEPHALOPODS FROM THE LA PEÑA FORMATION)

BY WILLIAM E. HUMPHREY

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ABSTRACT

The Sierra de Los Muertos area is part of the rugged mountainous country southeast of Saltillo in northeastern Mexico. It includes about 14,000 feet of Jurassic and Cretaceous rocks that were deposited along the eastern border of the Mexican geosyncline, a trough developed along the western and southern margins of the Coahuila platform. Early in the Tertiary these rocks were compressed into folds parallel to the borders of the platform. In the mapped area the folds are generally overturned to the north, but some are doubly recumbent.

The Jurassic includes the Zuloaga limestone of Oxfordian age and La Casita formation of Kimmeridgian-Portlandian age. The Cretaceous from the base upward includes the Taraises formation of lower Neocomian age, the Cupido limestone of upper Neocomian-lower Aptian age, the La Peña formation of upper Aptian age, the Aurora limestone of lower and middle Albian age, the Cuesta del Cura limestone of upper Albian age, the Indidura formation of Cenomanian-Turonian age, and the Parras shale of Coniacian-Santonian age.

The La Peña formation contains a large fauna of mollusks, brachiopods, and echinoids. Ammonites dominate the fauna and include such characteristic Aptian genera as *Dufrenoya*, *Parahoplites*, *Acanthoplites*, *Hypacanthoplites*, *Cheloniceras*, *Colombiceras*, *Uhligella*, and *Pseudohaploceras*. New genera include *Burckhardtites* and *Megatyloceras*. Nautiloids are represented by *Paracymatoceras*. A total of 42 species of cephalopods is described.

INTRODUCTION

The Sierra de Los Muertos area, in northeastern Mexico, comprises about 120 square miles of rugged mountainous terrain in the Sierra Madre Oriental along both sides of the boundary between southeastern Coahuila and southwestern Nuevo León (Figs. 1, 2). The northeastern corner of the area mapped (Pl. 1) is approximately half way between Saltillo, Coahuila, and Monterrey, Nuevo León. The national highway between those two cities roughly marks the northern and western limits of the region investigated. The mapped area is rectangular, extending east-west about 13½ miles and southward about 9 miles.

From a point on the Saltillo-Monterrey highway about 6 miles north of Ramos Arizpe, Coahuila, a secondary automobile road extends to Hacienda San Jose de Anuncios, the largest ranch in the area. From San Jose, unimproved roads, passable

FIGURE 1.—*Index map of northern Mexio*

by automobiles only in dry weather, extend to the Congregacion de San Lucas and eastward up the Cañón de La Escalera to Cañón de Los Placeres and Rancho de Vino. Rincon de Las Vallas, on the Hacienda de Saucillo, may be reached by car from Saltillo via Arteaga. The mountains and valleys are covered by a network of foot and horse trails.

A base map showing the outlines of the mountain ranges was constructed by use of plane table and alidade on a scale of 1 inch = 2 miles. Most of the geological mapping within the area was done by pace and compass traverses from points located on the plane-table network. Altitudes were determined in some places by triangulation and vertical angles with the alidade and in others by aneroid barometer. Sections were measured by steel tape or were calculated from detailed pace and compass surveys.

The author spent 3½ months in the Sierra de Los Muertos area and in reconnaissance trips outside of the area.

ACKNOWLEDGMENTS

This paper is the latest in a series of regional geological studies in northern Mexico, sponsored jointly by The Geological Society of American and the Horace H. Rankham School of Graduate Studies of the University of Michigan. The writer is indebted to the two organizations for transportation to and from Mexico and for field expenses.

The field and laboratory studies were carried out under the supervision of Professor Lewis B. Kellum, to whom the writer is especially grateful for advice and criticism. To Dr. Ralph W. Imlay of the United States Geological Survey, thanks are rendered for numerous helpful suggestions on stratigraphical and paleontological problems encountered during the course of this study and for his good offices in arranging a loan of type material from the United States National Museum. Professor George M. Ehlers of the University of Michigan kindly advised the writer on taxonomic problems and made helpful suggestions relative to the technique of preparing illustrations of the fossils. Mr. Tracy V. Buckwalter, a graduate student in the Department of Geology of the University of Michigan, made the plane-table survey for construction of the base map. Mr. Walter A. Donnelley, Editor of Museums Publications of the University of Michigan, assisted with the orthography of the generic and trivial names.

The writer is indebted to Mr. W. H. Triplett, chief geologist of the Cia. Minera de Penoles, S. A., of Monterrey, for permission to live at the company's guest house at Las Palomas mine during a part of the summer of 1941. Dr. Alfredo Garza Moreira, owner of the Hacienda San Jose de Anuncios, was of considerable assistance during the field investigations.

Dr. Henryk B. Stenzel, of the Bureau of Economic Geology of the University of Texas, made available topotype material from the Texas Cretaceous for comparison with the Mexican Aptian ammonites described. Dr. A. K. Miller, of the State University of Iowa, kindly communicated information on the Aptian nautiloid herein described.

PREVIOUS INVESTIGATIONS

The Sierra de Los Muertos area was briefly mentioned by Böse (1906) who sketched the Upper Cretaceous stratigraphy and the regional tectonics along the route of the

railroad between Monterrey and Saltillo and postulated a large east-west fault along the Cañon de Los Muertos.

Between 1913 and 1922, Böse made numerous reconnaissance studies in the Sierra Madre Oriental south of Monterrey and east of Saltillo (1923b). Böse discussed the Jurassic and Cretaceous stratigraphy and illustrated the tectonics in a series of small-scale, cross-section sketches, but published no geological map. At the same time he abandoned his concept of a fault along the Los Muertos canyon, recognizing that the Los Muertos anticline is overturned (Pl. 1).

The writer agrees in general with the major stratigraphic subdivisions proposed by Böse. The present study presents the detailed areal geology of only a small part of the region covered by Böse.

GEOGRAPHY

TOPOGRAPHY

The Sierra de Los Muertos area forms part of the Sierra Madre Oriental of eastern Mexico. It consists of several westward-trending, subparallel mountainous ridges, cut by deep cross canyons and separated from one another by flat-floored, steep-sided valleys. The ridges are the topographic expressions of deeply eroded anticlinal folds. To the west, where erosion has not cut through the surface of massive limestones, they are rounded and die out beneath the widening valley floors. To the east, where erosion has cut through the massive limestones and exposed less resistant sediments, the topography is characterized by hogbacks and cuestas. Generally the mountains have elevations of 6000 to 8500 feet above sea level and local relief of 500 to 3000 feet. The highest topographic feature, the Sierra de La Calle, has an elevation of almost 9000 feet and lies along the eastern border of the area.

CLIMATE AND CULTURE

The Sierra de Los Muertos area has a semiarid climate, characterized by extreme diurnal changes in temperature. The plains and mountain slopes support a sparse vegetation, designated by botanists as Chihuahuan Desert Shrub. The most characteristic species of the flora is *Larrea tridentata* (DC.) Cov., and associated with it are *Flourensia*, *Acacia*, *Fouquiera*, *Prosopis*, *Parthenium*, and others (Muller, 1947, p. 38–41). The highest ranges support a sparse pine forest, indicative of a climate of reduced temperature and more precipitation than that of Chihuahuan Desert Shrub.

There are numerous ranches in the plain west of the mountains and along the Cañón de Los Muertos. San Jose de Anuncios, near the west end of Cañón de La Escalera, is the largest; it supports about 250 persons who raise stock, care for irrigated fruit orchards near the ranch headquarters, gather *candelilla* for wax, wood for charcoal, and *guayule* for rubber. The Congregacion de San Lucas, a ranch slightly smaller than San Jose, is located on the plain near the western end of the Sierra de San Lucas. The other ranches indicated on the map are much smaller.

REGIONAL GEOLOGICAL SETTING

The sedimentary rocks of the area are Jurassic and Cretaceous. They were deposited in the Mexican geosyncline (Imlay, 1938a), a trough developed along the western

border of the Coahuila Peninsula (Böse, 1923b; Kellum, Imlay, and Kane, 1936). This land mass was a southward-extending promontory of the North American Mesozoic continent. The sediments in the mapped area are mostly of an offshore facies. Only those of Portlandian-Tithonian (Late Jurassic) and Berriasian (Early Cretaceous) age appear to be of near-shore, coastal character. The Portlandian-Tithonian clastic materials coarsen toward the east and southeast (Böse, 1923b), indicating the presence of an elongate land mass or archipelago extending north-south in eastern Mexico during at least part of Late Jurassic time (Imlay, 1943b). Generally the Mesozoic formations change in facies across the strike of the Mexican geosyncline (Imlay, 1938a) and away from the shore lines and influence of the Coahuila Peninsula.

Probably early in the Tertiary, the deposits of the Mexican geosyncline were compressed into a series of folds parallel to the borders of the old land mass. South from Monterrey, the rather recently exhumed and dissected Laramide features form the north-south ridges and valleys of the Sierra Madre Oriental. Near Monterrey the Laramide folds (Böse, 1923b) branch as a result of a sudden change in strike from northwest to slightly south of west. Consequently the anticlines and synclines of the mapped area represent a structural continuation of the Sierra Madre of eastern Mexico. To the west, the folds plunge into the Parras Basin or curve strongly south in another abrupt change in strike near Saltillo and then continue west again as the Sierra de Parras along the south side of the Parras Basin.

The northernmost structure exposing rocks older than Upper Cretaceous in the mapped area (Pl. 1) is the Los Muertos anticline. North of it is a synclinorium of Upper Cretaceous beds corresponding to the synclinorium of the Parras Basin farther west. South of this area is a series of large, closely packed, anticlinal folds composed chiefly of Lower Cretaceous and Upper Jurassic sediments. The individual structures are characteristically overfolded to the north and may be doubly recumbent with both the north and south flanks inclined in a pseudo-synclinal manner toward the anticlinal axes. The easily eroded Upper Cretaceous rocks usually are preserved in the major synclinal valleys. The main mountain masses are formed of thick Lower Cretaceous limestones which constitute the crests and flanks of the large anticlinal folds and commonly bound axial strike valleys which have been excavated in the less resistant Upper Jurassic sediments.

STRATIGRAPHY

The sedimentary rocks exposed in the area are at least 14,500 feet thick. They were deposited under dominantly marine environments during the Late Jurassic and the Cretaceous. Approximate thicknesses of the formations mapped (Pl. 1) are as follows:

	Feet
Quaternary:	
Recent alluvial materials	0 to 200±
Upper Cretaceous:	
Parras shale	4500+
Indidura formation	1800+
Lower Cretaceous:	
Cuesta del Cura formation	400 to 500
Aurora limestone	1000 to 1500

La Peña formation	25 to 135
Cupido limestone	2000 to 2500
Taraises formation	850±
Upper Jurassic:	
La Casita formation	2190±
Zuloaga limestone	300+
Total	13,265 to 14,475+

JURASSIC SYSTEM

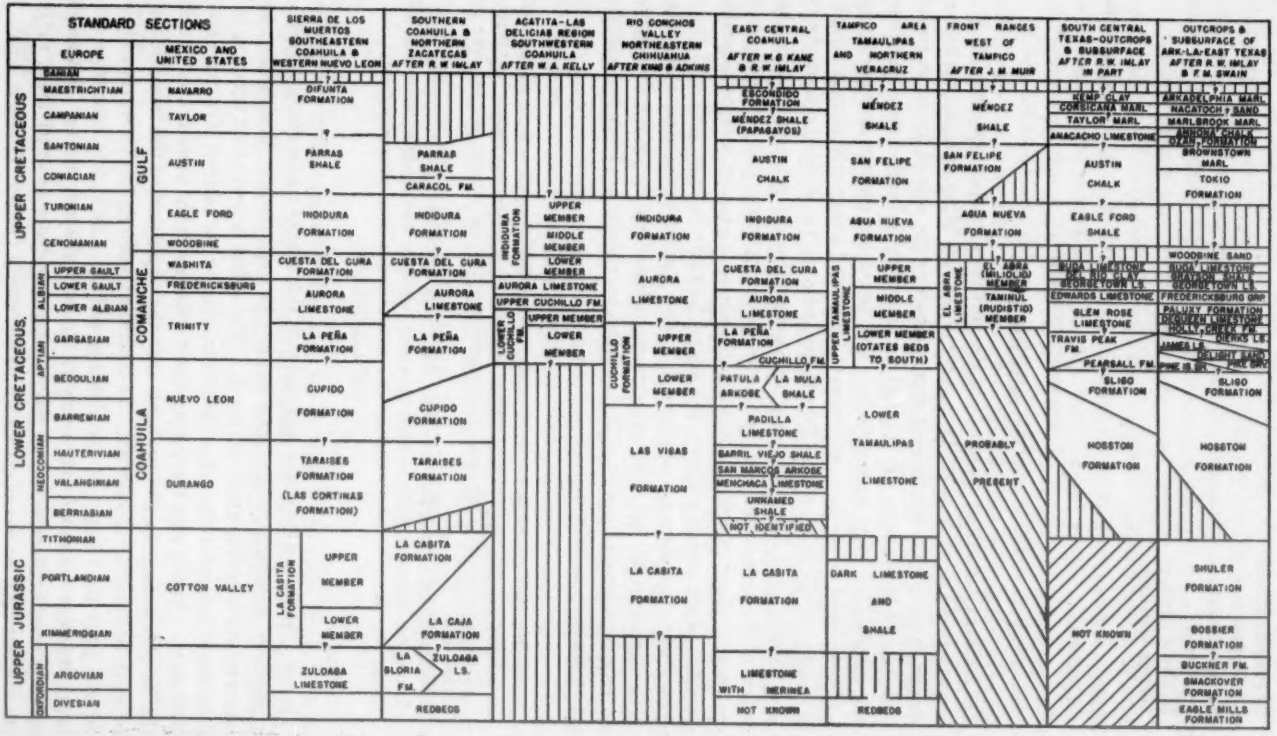
ZULOAGA LIMESTONE

The Zuloaga Limestone crops out in the northwest part of the area (Pl. 1), where it forms a strike ridge or *morro* in the core of the Los Muertos anticline, and extends eastward in practically continuous exposures along the axis of the same structure to the vicinity of Monterrey. It consists of thin- to thick-bedded gray limestones with minor interbedded gray, earthy shale. The limestones contain abundant gray, rust-weathering chert in the form of elongate lenses and irregularly shaped nodules. At one locality on the south side of Puerto del Indio, on the divide between the canyons of Las Cortinas and San Juan, some thin seams of white gypsum occur in the upper few feet of the formation. In the Cañón de Las Cortinas, just south of Los Chupaderos ranch, about 300 feet of Zuloaga limestone is exposed and considerably marmorized. Much coarse-grained, secondary dolomite is developed, and the original sedimentary characters are obscured. About 2 miles to the west along the strike, a little more than 200 feet of Zuloaga limestone is well exposed where the upper Arroyo San Juan cuts across the axis of the Los Muertos anticline. From top to bottom, the section there is as follows:

Unit	*Feet*
3. Limestone, thin- to medium-bedded, shaly, medium gray, weathers light gray, contains interbeds 4 to 10 inches thick of light-gray, earthy shale. Limestones contain long stringers and irregular nodules of light-gray, rust-weathering chert, the latter up to 1 foot long and 4 inches wide	141
2. Limestone, thin-bedded, dark gray, very shaly, platy weathering, does not contain chert	32
1. Limestone, dolomitic, thick-bedded, dark gray, weathers medium gray, some beds 5 feet thick, very dense, contains concretion-like nodules of rust-weathering gray chert	39
Total	212

Imlay (1943b, p. 1485) has suggested that thinning of this formation from 1800 feet in northern Zacatecas to less than 400 feet in southwestern Tamaulipas indicates a major source of sediments in the north. The writer believes that thinning in Tamaulipas might indicate influence on sedimentation by the eastern Mexican Late Jurassic land mass. At any rate there is no direct evidence in the present area of a source for the Zuloaga sediments, and probably only the upper part of the formation is exposed between Saltillo and Monterrey. In both the Cañón de Las Cortinas and the Cañón de San Juan the contact of the Zuloaga and the Las Casita formations is a sharp break between limestone and overlying shales and sandy shales. Although no discordance can be demonstrated, paleontologic evidence in other areas suggests that the contact may be one of erosional unconformity (Imlay, 1943b, p. 1483).

TABLE 1.—*Correlation chart of Jurassic and Cretaceous formations*



In the Cañón de Las Palomas bedded gypsum was referred by Baker (1941) to strata equivalent to the basal part of the La Casita formation on the basis of correlation with bedded gypsum overlying the Zuloaga limestones at San Jose de Boquillas farther southeast in Coahuila. Böse (1923b, p. 203–204) did not mention bedded gypsum between the Oxfordian limestones and the fossiliferous middle Kimmeridgian shales, although he did report such a succession from the Sierra de La Marta, 20 miles farther south. This latter occurrence has since been correlated by Imlay (1943b, p. 1488) with the Olvido formation of Arnold Heim (1940, p. 318). The exposure of gypsum in Cañón de Las Palomas is related to a fault zone or zones, which probably have determined the position of the large cross-strike canyon at this place. The gypsum here is coarsely granular, structureless, and is exposed along the bottom and on the lowest wall of the canyon leading north from Puerto Las Palomas. It extends from the southernmost houses of the Mina Las Palomas to the trail on the steep slope leading up to the puerto. Along the zigzag part of the trail, the granular gypsum contains a 6-foot-square erratic block of thin-bedded, gray limestone. About 200 feet north, a large block of limestone and interbedded gypsum some 80 feet wide and 120 feet long (NW.-SE.) is surrounded by granular gypsum. Strike and dip on the block are exactly opposite to the regional directions. The western 40 feet of the exposure consists of gray limestone and gypsum in alternating beds from 6 inches to 2 feet thick. Thus the correct stratigraphic position of these beds cannot be determined in Cañón de Las Palomas. The lower part of the La Casita formation contains no gypsum or even gypsiferous shales 1½ miles east along the strike, nor has any bedded gypsum been reported from it in this immediate area. In a section across the eastern continuation of the Los Muertos fold just south of Santa Catarina, Nuevo León, dark shales of the La Casita formation rest directly on the limestones of the Zuloaga formation, as in the Las Cortinas and San Juan canyons. It would seem more probable that the gypsum of Las Palomas canyon is to be correlated with the thin streaks of gypsum observed near Puerto del Indio, in the Zuloaga limestone.

The writer has found no fossils in the Zuloaga limestone, although Böse (1923b) reported poorly preserved gastropods and corals, and the formation was referred to as the "*Nerinea* limestones" by both Böse and Burckhardt. According to Imlay (1943b, p. 1479), the Zuloaga limestone is the offshore equivalent of the La Gloria formation of eastern Durango and southern Coahuila, and the upper part of it, at least, is of Argovian (late upper Oxfordian) age. The writer believes the upper part of the Zuloaga formation here may be equivalent to at least a part of the Olvido formation farther south in the Sierra Madre Oriental.

LA CASITA FORMATION

In this area the La Casita formation is divisible into two members. They are well exposed in the core of the Los Muertos anticline where they form wide valleys and hill slopes around the outcrops of the Zuloaga limestone and inside the ridge-forming limestones of the Taraises formation. The upper member of the formation occupies the strike valley along the axis of the San Blas anticline, between the Sierra de La Calle and the Sierra de Los Placeres. It is poorly exposed in the Rincón de Potrerillos in the Sierra de San Lucas. East of the mapped area, in the large valley south of

Santa Catarina, Nuevo León, both members are well exposed in the eastern continuation of the Los Muertos anticline. To the south, the upper member is excellently exposed in the core of the large anticline at Boca de Arteaga, about 15 miles east of Saltillo.

The lower member is about 1000 feet thick and consists largely of brown, black, and dark-gray carbonaceous shales and sandy shales. It contains a few calcareous shales weathering light gray, in which occur one or two extensive zones of dense, dark-gray limestone concretions. The concretions are rounded, have a maximum diameter of 1 foot and are commonly fossiliferous.

The upper member consists of interbedded sandstones, sandy limestones, sandy and carbonaceous shales, and numerous beds of pebble and cobble conglomerates. The sandstones are commonly micaceous and conglomeratic and contain plant fossils. Many of the sandy limestones and conglomerates contain large, thick-shelled, oysterlike pelecypods. Extremely rapid lateral and vertical variation in lithology characterizes this member. No two sections are exactly alike in sequence, and individual units change rapidly in color, thickness, and composition along the strike. A fairly complete section through the La Casita formation (from top to bottom) was measured in the upper part of the Cañón de Las Cortinas, as follows:

Unit		*Feet*
27.	Limestone, medium- to thin-bedded, bluish gray, weathering platy; numerous shell fragments (*Exogyra*? sp.); thin interbeds of shales weathering dark brown	110
26.	Sandstone, medium-grained, greenish gray, weathering brown	3
25.	Limestone, sandy, massive, medium gray brown; weathers brownish to blue gray; shaly below	6
24.	Sandstone, thick-bedded, brown, conglomeratic lenses with quartz pebbles, some beds 3 feet thick; contains several thin beds of calcareous shale with shell fragments	95
23.	Limestone, sandy, thin- to medium-bedded, dark gray; weathers blue gray, pebbly conglomeratic streaks	5
22.	Sandstone, coarse-grained, dark gray; weathers white, pelecypod shell sections in basal 3 inches	19
21.	Shale, sandy, gray, thin-bedded, alternating with thin, blue gray beds of calcareous, soft-weathering shale	6
20.	Conglomerate, gray, pebbles up to 2 inches in diameter of quartz and chert, in beds 1 foot thick, with several thin beds of brown sandstone containing shell fragments	17
19	Shale, dark gray, tough, carbonaceous; weathers dark brown to black	22
18.	Sandstone, coarse-grained, brown; contains several 1-foot beds of conglomerate, with pebbles of white quartz to 1½ inches in diameter	23
17.	Shale, sandy, brown, alternating with calcareous shale weathering blue black; beds range from 3 inches to 1½ feet in thickness; contains several 1-foot beds of pebble conglomerates, becoming more sandy below	230
16.	Sandstone, medium-grained, light gray, massive	6
15.	Shale, similar to unit 11, but more calcareous, becoming sandy below	46
14.	Shale, black, fissile, carbonaceous; weathers black and dark brown. Contains numerous lenses 4 to 6 feet thick of dark gray, shaly limestone, composed almost entirely of a small species of *Exogyra*	161
13.	Sandstone, medium- to coarse-grained, light gray, micaceous, becoming shaly below and containing quartz pebbles ¼ inch in diameter	12
12.	Shale, fissile, black; contains numerous limy lenses with small, poorly preserved oysters	41
11.	Shale, sandy, blue gray; contains quartz pebbles to 1½ inches in diameter	24

Unit		*Feet*
10.	Sandstone, medium- to coarse-grained, thin- to thick-bedded, light gray; becoming shaly, weathering platy, brown in middle third; lower third is conglomeratic, dark brown; contains large, poorly preserved species of *Trigonia*	210
9.	Shale, calcareous, fissile, bluish black	46
8.	Sandstone, coarse-grained, gray; weathers brown; contains shell fragments, quartz, and chert pebbles	2
7.	Shale, calcareous, black and brown weathering	14
6.	Sandstone, medium-grained, pebbly, dark gray, containing shell fragments	5
5.	Shale, gray, hackly; weathers light gray	12
4.	Sandstone, coarse-grained, massive-bedded, conglomeratic; weathers medium gray with brown bands	41
3.	Shale, sandy, calcareous; weathers gray to blue gray, banded; contains large, poorly preserved, oysterlike pelecypods	32
2.	Limestone, sandy, composed almost entirely of internal casts of unidentifiable pelecypods	3
1.	Shale, brown, black, gray, carbonaceous, commonly sandy, more rarely calcareous with dense, dark gray, rounded and ovoidal limestone concretions	1000±
	Total	2190±

The base of the sandy limestone of unit 2 has been arbitrarily chosen as the lower limit of the upper member of the La Casita formation in this section. To illustrate variations in the lithology of the upper member comparison may be made with the section measured by Böse (1923b, p. 205) in the Boca de Arteaga, which is about 12 miles east of Saltillo and about 20 miles southwest of the Las Cortinas section. Böse's section, 1272 feet thick, shows most of the upper member of the La Casita formation, but the lower member is not exposed in the Boca de Arteaga. In the valley south of Santa Catarina, the upper member consists of about 900 feet of red, brown, and yellow sandstones and conglomerates containing beds of large oysterlike pelecypods near the middle of the series. Both Böse (1923b, p. 131) and Imlay (1943a, p. 527) have indicated that a source for these coarse clastic sediments must have existed to the east and northeast as an elongate southwardly trending land mass or as a string of islands in late Jurassic time. Locally, however, a part of the land mass may have extended considerably to the westward since a comparison of the two sections suggests an overall thickening and increase in sandstones and coarse conglomerates to the south or southeast. Exposures of the upper member in the Sierra de San Lucas also show much coarser and more extensive conglomerates than does the Las Cortinas section.

The lower member of the La Casita formation is rather uniform lithologically throughout the area mapped and appears to be much thicker than equivalent beds in other parts of northern Mexico (Imlay, 1943b, p. 1485 et seq.) except possibly the section near San Pedro del Gallo, Durango (Burckhardt, 1912; Imlay, 1938a, p. 1685). In the core of the eastern continuation of Los Muertos anticline south of Santa Catarina, the lower member of the La Casita formation is estimated as 800 ± feet thick and is mostly gray shales. The lower part of the member contains the zones of dark-gray limestone concretions with middle Kimmeridgian ammonites, whereas near the top of the member are intercalated thin fossiliferous limestones.

The writer found few fossils in the La Casita formation. The lower member

in adjoining areas has ammonites of Kimmeridgian age. The upper member contains abundant, but poorly preserved, pelecypod remains. Its lower part in the core of the San Blas anticline contains poorly preserved ammonites which probably belong to the Portlandian *Virgatosphinctes*. The uppermost limestone unit of the upper member corresponds in stratigraphic position with beds which elsewhere carry species of *Kossmatia*.

The La Casita formation ranges from early Kimmeridgian to Tithonian in age. It is correlated with the Malone formation of western Texas and with the Cotton Valley group in the southeastern United States. Imlay has suggested (letter of May 20, 1947) that the upper member corresponds to the Shuler formation and the lower member to the Bossier formation of Swain (1944, p. 582, 594).

CRETACEOUS SYSTEM

TARAISES FORMATION (LAS CORTINAS FORMATION)

The Taraises formation was originally designated by Imlay (1936, p. 1111) for a series of limestones of early Neocomian age lying above clastics of the Upper Jurassic (La Casita formation) and below clastics of the Lower Cretaceous (Las Vigas formation). In 1944, Imlay (p. 1151) pointed out the lack of justification for the name Las Cortinas formation (Humphrey, 1941) because the beds to which it had been applied are only slightly different lithologically from the Taraises formation. The name Las Cortinas formation is therefore abandoned by the writer as synonymous with the Taraises formation.

The Taraises formation is well exposed on both flanks of the Los Muertos anticline from Cañón de Las Palomas eastward to the edge of the area. It crops out on the north and south slopes of the synclinal Sierra de La Calle and along the Cañón de San Blas. It is poorly exposed on the north flank of the San Lucas anticline. Most of the Taraises formation is easily eroded and forms saddles between hogbacks held up by its ridge-forming, basal limestone unit and by massive dolomites at the base of the Cupido formation.

In the present area, the Taraises formation is composed largely of calcareous gray shales with interbedded limestones. The shales predominate over the limestones which are marly, lenticular, and thin-bedded. Fossils are generally uncommon throughout but are relatively abundant in the basal beds. They consist mostly of distorted and poorly preserved ammonites belonging to lower Neocomian genera. In the northern part of the area, a thick reef of coralline limestone occurs at the base of the formation, and its lower contact has been arbitrarily chosen as the boundary between the Jurassic and Cretaceous. The coralline limestone appears to grade into underlying shales and limestones which are probably of Portlandian-Tithonian age. No evidence exists in this area for a physical break between the Jurassic and Cretaceous. The upper contact of the Taraises formation is concordant with thick-bedded dolomites and limestones of the Cupido formation.

An excellent section through the entire Taraises sequence is exposed near the head

FIGURE 1. LA PEÑA FORMATION, UPPER PART
Thin beds of limestone and shale on north flank of Los Muertos anticline.

FIGURE 2. LA PEÑA FORMATION, LOWER PART
Medium-bedded limestone rests on massive Cupido limestone at man's feet. North flank of Los Muertos anticline.

FIGURE 3. INDIDURA FORMATION, UPPER MEMBER
Shale and limestone on south side of Mesa de San Antonio.

LA PEÑA AND INDIDURA FORMATIONS

FIGURE 1. RINCON DE SAN GREGORIO, NORTH FLANK OF LOS MUERTOS ANTICLINE
Relief of about 2000 feet. Mountains composed of thick-bedded limestones of the Cupido and Aurora formations.

FIGURE 2. CAÑON DE LOS PLACERES, SOUTH FLANK SAN BLAS ANTICLINE
Sierra de Los Clavellinas in background composed of Aurora and Cuesta del Cura formations. In left middle distance are vertical thick-bedded limestones and dolomites of the Cupido formation.

MOUNTAIN RANGES

of Cañón de San Juan on the north flank of the Los Muertos anticline. From top to bottom, the formation is as follows:

Unit		*Feet*
9.	Shale, powdery, gray, calcareous, with thin lenses and beds (2 to 4 inches thick) of dense, dark gray limestone	42
8.	Limestone, medium-bedded (2 to 2½ feet thick), dense, dark blue gray, weathering brown; alternating with platy, marly beds of equal thickness	25
7.	Shale, gray, weathering brown yellow, containing thin layers of gray platy limestone about 1 foot in thickness	109
6.	Shale, calcareous, gray, weathering buff, splintery	347
5.	Limestone, massive-bedded, gray, dense, weathering bluish gray; some beds of dark gray calcareous shale	114
4.	Shale, brown gray, laminated, splintery, weathering dark brown, containing irregular beds, lenses, and nodules of dark gray limestone	39
3.	Shale, brown, weathering dark brown, noncalcareous, containing numerous veins of white calcite up to 3 inches thick	20
2.	Shale, powdery, gray, weathering light gray, with numerous thin, dark gray limestone lenses and nodules, ammonites	49
1.	Limestone, gray, weathering light gray, thick-bedded to massive; some beds largely composed of bryozoans and corals, becoming somewhat shaly below	104
	Total	849

The upper part of the formation seems to gain in lime content to the east and south. However, the basal reef limestone grades into shales to the east and is missing in the canyon south of Santa Catarina. It is represented in the Sierra de San Lucas by only 10 to 12 feet of gray, massive, fossiliferous limestone. Böse (1923b, p. 210) has shown that the lithologic units are extremely local features and that their succession varies considerably from place to place between Saltillo and Monterrey. The general lithologic make-up of the formation, however, is constant over a considerable area.

The writer noted two distinct zones of ammonite-bearing strata in the lower part of the Taraises formation. One, in beds very near the contact of units 2 and 1 of the above section, has yielded specimens here referred to *Berriasella*, *Spiticeras*, and *Neocomites* sp. *Berriasella* and *Spiticeras* together would indicate a Berriasian age. Another zone, 25–30 feet stratigraphically above the first, contains species referred provisionally to *Olcostephanus*, *Acanthodiscus*, *Neocomites*, *Thurmannites*, and *Distoloceras* and may be of late Valanginian age, although Imlay (1938b, p. 552) has shown that such an assemblage in northern Mexico is likely to be of early Hauterivian age. Probably most of the formation above unit 2 in the San Juan section is of late Hauterivian age.

CUPIDO LIMESTONE

The Cupido limestone is the major mountain-forming formation in southeastern Coahuila and southwestern Nuevo León (Pl. 3). It crops out widely in the Sierra de Los Muertos and forms the core of the Los Muertos anticline from Cañón de Las Palomas to Rincon de Las Boquillas at the west end of the range. In most places it constitutes the middle or upper slopes of the mountains. The highest topographic features

in the area, the Sierra de La Calle and Picacho de Los Galapitos, are formed of highly resistant Cupido strata. The formation forms huge, picturesque strike ridges on the flanks of the anticlines as may be seen in the Huasteca canyon, south from Santa Catarina, Nuevo León, and also in the Puerto del Jardin, in the Sierra de Las Navajas.

The Cupido limestone consists of thin- to thick-bedded and massive limestones, dolomitic limestones, and dolomites, with thin intercalated shales. It ranges from 2000 to 2500 feet in thickness. The upper three-fourths is generally medium- to thick-bedded and cherty; the lower one-fourth medium- to thin-bedded and more shaly, while the base is everywhere marked by a thick-bedded unit of dolomite and dolomitic limestones. The contact with the overlying shales and marly limestones of the La Peña formation is sharp and though concordant may represent an erosional unconformity. In an unnamed canyon near the western end of the Sierra de Los Muertos and in other localities, the upper surface of the Cupido limestones is wavy, and the hollows are commonly filled with shell debris and small, unidentified, oyster-like pelecypods. The formation is fairly uniform throughout the area. Because of strong overfolding in the Sierra de San Lucas, it is difficult to obtain true thicknesses, but the Cupido formation may thin toward the south. It is well exposed in the northerly trending Cañón de Las Cabrillas, southeast of Higueras on the north flank of Sierra de Los Muertos. The section there, from top to bottom, is as follows:

Unit		*Feet*
15.	Limestone, medium-bedded, dolomitic, dark gray, dense, weathers dark bluish gray, beds 2 to 3 feet thick, contains irregularly shaped nodules of gray, rust-weathering chert, partly covered	500
14.	Limestone, gray, thin-bedded (10 inches to 1½ feet thick), contains some cherty zones, alternates with thin beds of dark gray shale, partly covered	420
13.	Limestone, thick- to massive-bedded, dark gray, dense, weathers bluish gray	16
12.	Shale, greenish gray, weathers dark brown, contains lenses of platy, dark gray limestone	8
11.	Dolomite, dark gray, massive, finely crystalline, weathers dark gray	6
10.	Limestone, gray, dense, medium-bedded, weathers blue gray, alternating with 1-foot bands of thin (2 to 3 inches thick), platy limestone	22
9.	Dolomite, dark gray, medium-textured, thick-bedded (5 to 6 feet thick), weathers brown	42
8.	Covered	20
7.	Limestone, dolomitic, thin- to medium-bedded, dark gray, weathers gray, some beds 2½ feet thick	39
6.	Limestone, thin- to medium-bedded, light gray, weathers light gray	72
5.	Dolomite, light brown, medium-bedded, weathers buff color, medium-textured, numerous calcite veins	29
4.	Limestone, gray, thin-bedded (3 to 8 inches thick), weathers light gray, thicker and dolomitic below	125
3.	Dolomite, thin- to medium-bedded, dense, dark gray, weathers gray brown	170
2.	Limestone, brown gray, thin- to medium-bedded (from 10 inches to 2½ feet thick), weathers gray, intercalcated with 2 to 3 inch beds of light-brown, gray-weathering, hackly shales. Some limestone beds 5 feet thick	650
1.	Dolomite, steel gray, coarsely crystalline, thick-bedded (3 to 10 feet thick), weathers black	125
	Total	2244

The writer found no fossils, other than a few rudistid fragments and some unidentifiable pelecypod sections. However, the stratigraphic position of the Cupido

formation indicates that it is of Barremian and early Aptian (Bedoulian) age, and its basal beds may include part of the upper Hauterivian.

LA PEÑA FORMATION

Imlay (1936, p. 1119) named the La Peña formation for the "lower and middle portions of the mountain-forming limestones, as exposed in the Sierra de Parras, lying stratigraphically between the Parritas formation (below) and the Aurora limestone (above)." He divided the La Peña formation into two members—a lower one, 1000 to 1400 feet thick composed of thin- to thick-bedded limestones with some shaly partings, and an upper member of thin-bedded marly limestones and shales 50 to 80 feet thick containing an ammonite fauna of Gargasian age. Imlay's lower member corresponds in stratigraphic position and lithology to the upper part of the Cupido formation of this report. His upper member corresponds to what has been mapped here as the La Peña formation. The writer believes the La Peña formation should be restricted to the lithologically distinct unit of marls, shaly limestones, and shales which carries a late Aptian fauna and which is extensive throughout northern Mexico. The name is so used in the present study (Pl. 2, fig. 1).

The La Peña formation commonly forms narrow strike valleys and talus-covered terraces between the mountain-forming masses of the Cupido and Aurora limestones. Exposures are usually limited because the formation weathers easily into soils and because the narrow and topographically low outcrop strips are commonly covered by debris from the adjoining thick limestone formations. In the overturned north flank of the San Lucas anticline, the formation may be locally absent due to structural thinning or faulting. La Peña formation is best preserved in the narrow syncline of the Rincon de Las Vallas in the southwestern portion of the mapped area.

In the mapped area the La Peña formation consists of 25 to 135 feet of red- to pinkish-weathering gray marls interbedded with thin, light- to dark-gray shaly limestones and thin beds of dark-gray to black laminated shales. It commonly contains lenses and stringers 1 to 3 inches thick of black chert. Characteristic of the formation is the uneven bedding, and from a distance the outcrop belt is red or pinkish. In the Sierra de Parras, the La Peña formation (upper member of Imlay) thickens southward from 50 to 300 feet across the regional strike of the Mexican geosyncline (Imlay, 1937, p. 607). In the present area, however, it apparently thins southward. In and south of the Sierra de San Lucas, the lower two-thirds of the formation passes into medium-bedded gray limestones which resemble those of the Cupido limestone. Throughout the Sierra de Los Muertos, the La Peña formation is fairly constant in general lithologic characters and thickness although individual beds may intergrade laterally and change rather rapidly in lithologic character. The contact with the underlying Cupido formation is concordant but may be unconformable. The contact with the overlying Aurora formation is concordant and probably conformable but does not seem to be gradational. In a small strike valley excavated in the formation on the east side of the Rincon de San

Gregorio (north flank-Los Muertos anticline), a section measured by the writer is as follows:

Unit	*Feet*
6. Limestone, dense, unevenly bedded, dark gray, weathers light gray, beds 8 inches to 1 foot thick, alternating with shales of equal thickness, dark gray brown, weathering pinkish, contains a few belemnites and echinoids, partly covered	19
5. Shale, calcareous, brown, weathers brownish gray, beds 1 to 1½ feet thick, with interbeds of limestone, gray, earthy, 5 to 10 inches thick, very fossiliferous, contains *Burckhardtites*, *Parahoplites*, *Cheloniceras*, *Dufrenoya*, *Neohibolites*, numerous clams, small gastropods, and abundant echinoids	16
4. Limestone, dense, dark gray, weathers gray, beds to 1½ feet thick, with interbeds of marly shale, gray, weathering pinkish, contains few indeterminate ammonites, many small pelecypods	15
3. Shale, marly, brown, weathers reddish, beds 1 to 2 feet thick, containing selenite; with interbeds (4 inches to 1 foot) of limestone, powdery, light bluish gray, contains numerous ammonites, *Dufrenoya justinae* (Hill), *Cheloniceras*, *Parahoplites*, ancyloceratids, and many oysterlike pelecypods	15
2. Limestone, light gray, weathers pinkish gray, nodular, unevenly bedded, beds 5 to 10 inches thick; thinner interbeds of shale, dark gray, laminated, containing pelecypods and uncoiled ammonites, *Tonohamites?*, *Ammoniloceras?*	6
1. Limestone, dark gray, thin- to medium-bedded, very irregularly stratified, lenticular, earthy, with thin interbeds of shale (4 to 8 inches thick), marly, brown gray, weathers reddish, contains poorly preserved pelecypods, *Plicatula?*, *Exogyra?*	40
Total	111

The La Peña formation commonly contains a rich fauna of cephalopods, other mollusks, brachiopods, and echinoids of late Aptian (Gargasian) age. The fauna was first noted by Burckhardt and Villarello (Burckhardt, 1909, p. 120–121) in the Río Nazas valley in Durango. In 1925 Burckhardt described 30 species of cephalopods from the same locality, 15 of which were figured as new. He referred to the ammonite-rich strata of the La Peña formation as the "Capas con *Douvilleiceras*" (= *Douvilleiceras* (*Cheloniceras*) beds). Summarizing worldwide occurrences of the upper Aptian, he pointed out the great similarity of the Río Nazas fauna with that which Kilian (1913, p. 292) had called the "Type occidental" in the southeast of France. At the same time Burckhardt (1925, p. 51) indicated that the La Peña fauna had as much in common with the upper subzone (*subnodosocostatum*) of the Gargasian as with the lower subzone (*martinii*). He further showed (p. 52–53) that the base of the thick series of limestones (Aurora limestone of the present report) overlying the La Peña formation along the Río Nazas probably belonged to the "Clansayes Horizon" of Jacob (= *nodosocostatum* zone of the lowermost Albian). Böse (1923b, p. 211–212) cited a few fossils from a locality in the Rincón de Las Vallas in the southwestern part of the present map area as belonging to the Río Nazas fauna. Later, from the same locality, Böse and Cavins (1927, p. 19–20) listed 38 species of fossils, none of which was described or figured.

In the Systematic Paleontology, the writer has described and figured from the La Peña formation 42 species of cephalopods belonging to 11 genera. Of these, 2 genera and 28 species are described as new. The forms include only a few of those previously treated by Burckhardt. The total of the species now described from the

La Peña formation represents only a part of the exceedingly prolific upper Aptian fauna of these beds. There remains in the collections of the University of Michigan from northern Mexico a large number of cephalopods, other mollusks, echinoids, and brachiopods which, augmented by better-preserved examples, will certainly merit description at some future time.

The present study of the ammonites of the La Peña formation includes only the families Parahoplitidae, Cheloniceratidae, and Desmoceratidae.

The Parahoplitidae are represented by 5 genera, including 26 species. *Dufrenoya*, *Parahoplites*, *Burckhardtites* Humphrey n. gen., and *Acanthoplites* are abundant and characteristic of the ammonite fauna. *Hypacanthoplites* is rather uncommon and is represented by 2 species, one of which is assigned with question to that genus.

The Cheloniceratidae include 3 genera and 9 species. *Cheloniceras* is one of the most common ammonite genera in the La Peña strata, and to this genus is now referred most of the species assigned to *Douvilleiceras* by Burckhardt. *Megatyloceras* Humphrey n. gen. and *Colombiceras* are each represented by only one species.

The Desmoceratidae in the La Peña fauna are represented by a number of specimens constituting 6 species of the genera *Uhligella* and *Pseudohaploceras*?.

Nautiloids of the family Cymatoceratidae are represented by one species of *Paracymatoceras*.

As was suggested by Burckhardt (1925, p. 51), both zones of the upper Aptian of Europe appear to be represented by the La Peña formation. In the regrettable lack of data regarding the exact range of species within the formation, two conclusions are indicated. Either there is a zonal succession more or less equivalent to that pictured by Spath (*see* Table 2), with the upper fossiliferous beds of the formation representing the *subnodosocostatum* zone and the lower, the *martinii* zone; or the La Peña strata were deposited midway in time between these zones and thus partake of faunal characters common to both. The occurrence together of *Cheloniceras*, *Dufrenoya*, and *Colombiceras* certainly indicates a correlation with the *martinii* zone. The association of *Parahoplites*, *Acanthoplites*, and species of *Cheloniceras* like *C. subnodosocostatum* (Sinzow) or *C. caucasicum* (Anthula) and abundant belemnites (*Neohibolites*?) point to a correspondence with the *subnodosocostatum* zone. It is of interest to note that in the section given a species of *Dufrenoya* like *D. dufrenoyi* (d'Orbigny) occurs in unit 5, or the topmost of the two most fossiliferous zones, suggesting that the genus may range higher in the western hemisphere than it appears to in Europe.

The striking resemblance of the La Peña fauna to that of the "Type occidental" in southeast France lies not only in identity or close relation of many of the genera and a few of the species in the two regions, but in the notable absence in both assemblages of the families Phylloceratidae and Lytoceratidae, predominant in the "Type oriental" or eastern facies of Kilian (1913, p. 292). Böse and Cavins (1927, p. 21) pointed out the affinity of the La Peña fauna with that described by Sinzow (1898 *et seq.*) from Saratow in southwestern Russia. Somewhat different from Sinzow's fauna and perhaps closer to the La Peña assemblage are the forms described by Kasansky (1914) from Daghestan. Less surprising is the close relationship of part of the La Peña fauna with species described by Riedel (1937) from Colombia.

It is doubtful that the upper part of the La Peña formation in the present area includes beds of lower Albian age, as has been suggested by Imlay (1938a, p. 1664; 1944, p. 1092, 1093). The writer has seen no ammonites referable to *Diadochoceras*

TABLE 2.—*Correlation of Mexican strata with ammonite zones in Europe*

SUBSTAGE	ZONE*	SUBZONE*	SOUTHEASTERN COAHUILA	
LOWER ALBIAN	tardefurcata (Leymeriellan)	regularis milletianum schrammeni	AURORA FORMATION (LOWER PART)	Orbitolina Rudistids
"CLANSAYES HORIZON"	nodosocostatum (Acanthoplitan)	jacobi nolani		
UPPER APTIAN (GARGASIAN)	subnodosocostatum (Parahoplitan)	aschiltaensis nutfieldensis	LA PEÑA FORMATION	Hypacanthoplites Parahoplites Acanthoplites Burckhardtites Cheloniceras Megatyloceras Dufrenoya Colombiceras Uhligella Pseudohaploceras? Tonohamites? Ammonitoceras Neohibolites? Spatangids Exogyra
	martinii (Tropaeuman)	tovilense bowerbanki hillsi		
LOWER APTIAN (BEDOULIAN)	deshayesi (Deshayesitan)	consobrinoides hambrovii weissi bodei	CUPIDO FORMATION (UPPER PART)	Requienia Monopleura
	recticostatus (Parancyloceratan)	bidentatus rude sparsicosta		

*modified after L. F. Spath

Hyatt (*nodosocostatum* zone) in collections from the La Peña formation or its equivalents. *Parahoplites* cf. *P. multicostatus* Sinzow, cited by Burckhardt (1930, p. 143) from the "Bufa de Cabrillas" (Cañón de Cabrillas?) in the present area and considered by Imlay (1944, p. 1152) as indicating the possible presence of lower Albian in the upper La Peña formation is not conclusive. *Parahoplites multicostatus* Sinzow originally was described from strata probably belonging to the *subnodosocostatum* zone of Mangyschlaks, Russia, and a similar form has been cited by Spath (1930, p. 441) from the upper *subnodosocostatum* zone of England. The

absence of *Orbitolina* in the upper La Peña beds is a negative argument against an Albian age, since, as Imlay (1945b, p. 1448) has remarked, that genus is uncommon below the Albian in the Gulf Region.

The La Peña formation corresponds to (1) the lower part of the upper Cuchillo formation in northeastern Chihuahua (2) the lower member of the Cuchillo formation in the Acatita-Las Delicias area (Kelly, 1936) of southwestern Coahuila, (3) part of the Otates member (Muir, 1936, p. 28) of the Tamaulipas limestone of southern Tamaulipas, and (4) most of the Travis Peak formation of the outcrop in central Texas.

AURORA LIMESTONE

As a mountain-forming element the Aurora limestone is second in importance only to the Cupido limestone. It crops out widely in the western part of the Sierra de Los Muertos where it forms the crests and flanks of the anticlinal mountains. To the east in the same range and in the Sierra de Los Placeres, it crops out in wide bands along the lower slopes of the mountainous ridges. Dip slopes of Aurora limestone form the flanks and crest of the Sierra de Las Clavellinas and of the Cerro de Enmedio. In the Sierra de San Lucas and in its continuation to the east as the Sierra de San Lucas and in its continuation to the east as the Sierra de Las Navajas, the formation is topographically low and poorly exposed along the base of the range where it is commonly covered by debris from the inverted and higher Cupido formation (Pl. 3).

The Aurora limestone ranges from 1000 to 1500 feet in thickness. Böse (1923b, p. 212) gave a thickness of 1000 meters (3280 feet) for equivalent beds in the same region, but, since he recognized the presence of the upper Aptian marls at only one locality, his figure may include part or all of the Cupido limestone of the present report. The Aurora limestone is almost entirely medium- to thick-bedded and massive, gray, rudistid-bearing, reef limestones which characteristically contain varying amounts of chert in the form of irregularly shaped nodules and concretions. The contact with the underlying La Peña formation is sharp but seems to be conformable. The contact with the overlying Cuesta del Cura formation is concordant and appears to be gradational. Beds of the Aurora limestone range from 1 to 20 feet in thickness and average about 3–5 feet. Massive beds are more common in the lower part of the formation, and thinner beds containing partings of gray calcareous shale are predominant above. Fresh surfaces of the dense limestones are dark gray to dark bluish gray and weather medium to light gray or light brown. The chert nodules are dark gray to black, average about 3 inches in greatest diameter, and weather a rust brown. Some may be over 2 feet in length and 4 or 5 inches through. They occur disseminated through the thick beds of limestone and not in definite layers as in the Cuesta del Cura formation. Development of stylolites on a grand scale is common in the massive limestones. Transverse and longitudinal sections of rudistids were observed throughout the formation but are most abundant in the upper part.

The Aurora limestone was named by Burrows (1910, p 96–97) for 600 to 1500 feet of cherty limestones in the Sierra de La Aldea, along the valley of the Rio Conchos in

northeastern Chihuahua. King and Adkins (1946, p. 286) indicate that the formation in the type area is about 5000 feet thick and state, "... the lower massive member of the formation contains rudistids and *Orbitolina* and is at least partly of Glen Rose age." The strata called Aurora limestone in the area of this report have a stratigraphic position and facies similar to the formation in the type locality. They probably are of early and medial Albian age and correlate with the Glen Rose and Fredericksburg of Texas. The Aurora limestone in the Acatita-Las Delicias area (Kelly, 1936), however, appears to be considerably younger and probably correponds only to the uppermost part of the Aurora and all of the Cuesta del Cura of this paper. Most of the strata here called Aurora limestone correspond to the upper Cuchillo formation and the upper member of the lower Cuchillo formation of Kelly. It would seem desirable to restrict the name Cuchillo to the lower shales, gypsum, and rock salt (Imlay, 1944, p. 1185) of probable Bedoulian age in the type area; correlate the upper beds which there contain *Dufrenoya* with the lower Trinity outcrops in Texas; and assign a new name to the gypsiferous facies of Albian age, called "upper Cuchillo" by Kelly (1936, p. 1026) in the Acatita-Las Delicias area. In eastern Mexico, the Aurora limestone correlates with the middle part of the upper Tamaulipas limestone of the Sierra de San Carlos and to the Taninul member of the El Abra limestone of southern Tamaulipas.

CUESTA DEL CURA FORMATION

The Cuesta del Cura formation crops out as dark-gray bands along the base of the mountain slopes, in marked contrast to the light-gray outcrop belts of the topographically higher Aurora limestones. Commonly the contact of the Cuesta del Cura with the overlying Indidura formation coincides with the topographic break between the mountains and the alluvium-covered valley floors. The formation is well exposed on the plunging west ends of all the anticlines in the area and probably is preserved beneath the alluvium in the synclinal canyon of Las Maravillas, west of the Cerrito del Muerto. It is well exposed all along the lower north wall of Cañón de Las Escaleras and on the north flank of the San Lucas anticline from Las Tetillas to the west end of the range (Pl. 2).

In the mapped area, the Cuesta del Cura formation consists of 400 to 500 feet of beds 2 inches to 1½ feet thick of dark-gray, dense, almost lithographic limestone, which alternate with thinner beds of dark-gray, laminated shale, weathering light gray to yellowish, or with thin lenses and beds of black chert. The lenticularity of the chert stringers contributes to the notably wavy-bedded character of the strata. The lower contact with the underlying Aurora limestone appears to be transitional, and most sections show a division of the formation into a lower, thicker-bedded member and an upper member of thinner-bedded, more platy limestones which thin as the interbedded shales increase. The beds of the upper member average about 4 to 6 inches thick and contain relatively less chert. In the lower member the bedding is less wavy. The elongate lenses and thin beds of chert occur throughout and ordinarily do not show the rusty weathering of the more nodular chert in the Aurora limestone. Rarely a 3- to 4-foot limestone bed of typical Aurora lithology

is intercalated in a characteristic sequence of thin-bedded Cuesta del Cura limestones and shales. The upper contact with the Indidura is concordant and marked by the sudden appearance of thick beds of powder, gray shale of the basal Indidura. Incompetence of the Cuesta del Cura strata under deformation is shown by the numerous secondary knee folds and zig-zag crumplings whose axes are normal to the regional trends and which characterize all the exposures.

On the basis of lithologic and stratigraphic similarities the beds are considered equivalents of Imlay's (1936, p. 1125) Cuesta del Cura formation in the Sierra de Parras. The only fossils found were indeterminate *Inoceramus*, echinoids, and belemnites. However, about 15 miles south of the area, Böse (1923b, p. 213) reported that chert lenses in corresponding strata contained silicified uncoiled ammonites of late Albian age. The formation is believed to range from upper Albian to lower Cenomanian, and the facies it represents is of wide distribution in northern Mexico away from the Coahuila Peninsula.

INDIDURA FORMATION

Outcrops of the Indidura formation are restricted to small exposures in the synclinal valleys. The best exposures are in small outliers of the major ridges where the formation has been protected from erosion by caps of caliche-cemented gravels which are remnants of older erosional cycles. These include the Mesa de San Antonio and the Loma Pedrera on the north wall of Cañón de Las Escaleras; Las Tetillas, northwest of Picacho de Los Galapitos; and Cerro de Los Tanques, on the south wall of Cañón de Los Muertos, just west from Cañón de Las Palomas.

Pace traverses in the vicinity of Mesa de San Antonio indicate a minimum thickness of 1800 feet for the Indidura formation, but its contact with the overlying Parras shale was not observed. At least three lithologic units can be recognized. The lowermost unit consists of an estimated 800 to 900 feet of light-gray to yellowish-weathering, powdery and in places laminated, gray calcareous shales with lenses and thin interbeds of dark-gray limestones, weathering bluish gray. The shales contain selenite crystals and extensive secondary calcite veinlets. The limestone beds range from 2 inches to 1 foot in thickness and increase in number and thickness toward the base of the unit. Some of them contain echinoid sections and poorly preserved belemnites. The contact with the underlying Cuesta del Cura formation appears to be gradational.

The middle unit consists of 400 to 500 feet of finely laminated, "salt and pepper" shales which weather platy and alternate with thin-bedded sandy shales. The latter show thin color laminae and contain many veinlets of selenite. In the lower part of this unit, a 60-foot succession of dark-brown, somewhat sandy shales contains lenses of brown selenite up to 2½ feet thick.

The uppermost unit observed consists of 500 ± feet of platy, calcareous, gray shales, weathering yellow and brown, and light-gray shaly limestones, with minor amounts of thin, platy, sandy shales, weathering reddish. The platy limestones and shales range from 6 inches to 1½ feet in thickness and contain numerous small limonitic concretions and rare *Inoceramus* sp. The reddish streaks of sandy shale are selenitic (Pl. 2, fig. 3).

The Indidura formation was named by Kelly (1936, p. 1028) for about 100 feet of shales and limestones overlying the "Aurora" limestone in the Las Delicias area of western Coahuila. Studies by Jones (1938, p. 86–90) of fossils from the type locality indicate that the formation there ranges from upper Albian to Turonian, and thus the lower part of the formation in that area may be equivalent to part of what is here called the Cuesta del Cura formation. In the western part of the Sierra de Parras, Imlay (1936, p. 1127) has assigned more than 2000 feet of sediments to the Indidura formation and indicated for them a Cenomanian-Turonian age. On the basis of stratigraphic position the strata herein described are considered equivalent to the Indidura formation in the Sierra de Parras. The writer found only delemnite and echinoid fragments, indeterminate species of *Inoceramus*, and one poorly preserved ammonite (*Prionotropis* sp.?), the latter from the middle unit. Böse (1923b, p. 213–214) discussed equivalent strata in the immediate region as "Cenomanian" and "Turonian", but there is no field evidence on which to base such a distinction.

PARRAS SHALE

Strata here referred to the Parras shale occur in the Cañón de Los Muertos and in the western part of the synclinal Cañón de Las Escaleras. Good exposures are rare because the shale is generally covered by recent alluvium. An excellent section is exposed in the arroyo leading north from the Cañón de San Juan into the Cañón de Los Muertos. The Cañón de Los Muertos is excavated in Parras shales on the north flank of the Los Muertos anticline.

In the incomplete section north of Cañón de San Juan, the Parras shale is approximately 4500 feet thick. It consists largely of black or dark-brown shales interbedded with minor limestone and gypsum. The upper 800 feet consists of fissile brown shales which weather buff and contain platy concretions of brown limestone, 2 to 4 inches in diameter. Below, the shales are generally black, carbonaceous, and, in some places, gypsiferous. In the lower part of the exposure occur discontinuous layers of tuffaceous?, powdery shales, weathering light gray. The limestones are black, dense, 1 to 6 inches thick, and weather brown to yellowish. The beds of gypsum are finely laminated, range from 2 inches to 1 foot in thickness, and weather light brown to yellowish. In some places they contain quartz veins.

Just north of the area, the Parras formation is overlain concordantly by many thousands of feet of sandstones, shales, and conglomerates of *later* Upper Cretaceous age, which belong in part to the zone of *Exogyra ponderosa* and correlate with the Difunta formation of the Parras Basin (Imlay, 1936, p. 1133). The writer has not seen the contact of the Parras shale with the underlying Indidura formation.

The Parras shale was named by Imlay (1936, p. 1132) for about 5000 feet of shales above the Indidura formation and below the Difunta formation in the Sierra de Parras. No fossils were found in the Parras shale of the Los Muertos area but, on the basis of stratigraphic position, it is correlated with the Parras shale of the Parras Basin and is probably of Coniacian and Santonian age.

QUATERNARY SYSTEM

The Quaternary deposits in the area are most extensive in the intermontane valleys and in marginal lower country. They consist of terrace gravels of probable Pleistocene age and of channel deposits, flood-plain deposits, fanglomerates, and Piedmont debris of relatively recent origin that effectively conceal the bedrock geology.

STRUCTURAL GEOLOGY

GENERAL FEATURES

The structural history of the Sierra de Los Muertos area is intimately related to the site and character of the Coahuila Peninsula (Fig. 2; Pl. 1). The peninsula of Mesozoic time seems to have been a southward extension of the Ouachita-Marathon trend of the folded Paleozoic geosyncline of eastern North America. It seems doubtful that the orogen created by late Paleozoic diastrophism could have endured throughout more than early Mesozoic time. Possibly late Triassic or early Jurassic movements may have rejuvenated segments of the folded Paleozoic welt which served both as barriers to marine invasions from the Gulf region and as stable buttressing elements during the later Mesozoic. The Mexican geosyncline was initiated as a mobile belt on the foreland side of the Paleozoic welt, and its Mesozoic sediments were intensely folded by the Laramide movements. In contrast, in the Gulf region, Mesozoic sediments were deposited on the hinterland side of the Paleozoic welt and were disturbed very little in the United States and but erratically in Mexico during the Laramide disturbance. The tectonic history of the Mexican geosyncline has a western North American or Rocky Mountain aspect in contrast to the relatively uneventful history of the Gulf region deposits and those of the Atlantic coastal plain in general.

During the Jurassic there appears to have been intermittent movements in the land areas adjacent to the Mexican geosyncline. Perhaps the most important of these was in the late Kimmeridgian and early Portlandian and is related to the widespread Nevadan disturbance. In the Lower Cretaceous, minor and local movements in parts of the Coahuila Peninsula furnished some coarse clastics to the seaways. Although the Coahuila Peninsula was probably submerged by late Aptian time, it continued to act as a relatively high and stable mass over which the post-Jurassic sediments are considerably thinner than in the surrounding trough areas. In the Upper Cretaceous considerable thicknesses of sediments were deposited along the southern border of the Coahuila Peninsula in a trough whose position probably coincides with the marginal strip of land that bordered the upper Jurassic seas and which seems to have been positively mobile during the Nevadan disturbance.

Sometime in the Eocene, the deposits of the Mexican geosyncline were deformed into long narrow folds by forces acting more or less normal to the western border of the Coahuila Peninsula. The present topographic expression of the Laramide folds constitutes the Sierra Madre Oriental of northern and eastern Mexico. The front ranges of that orogen correspond to a line of overfolding which the writer believes

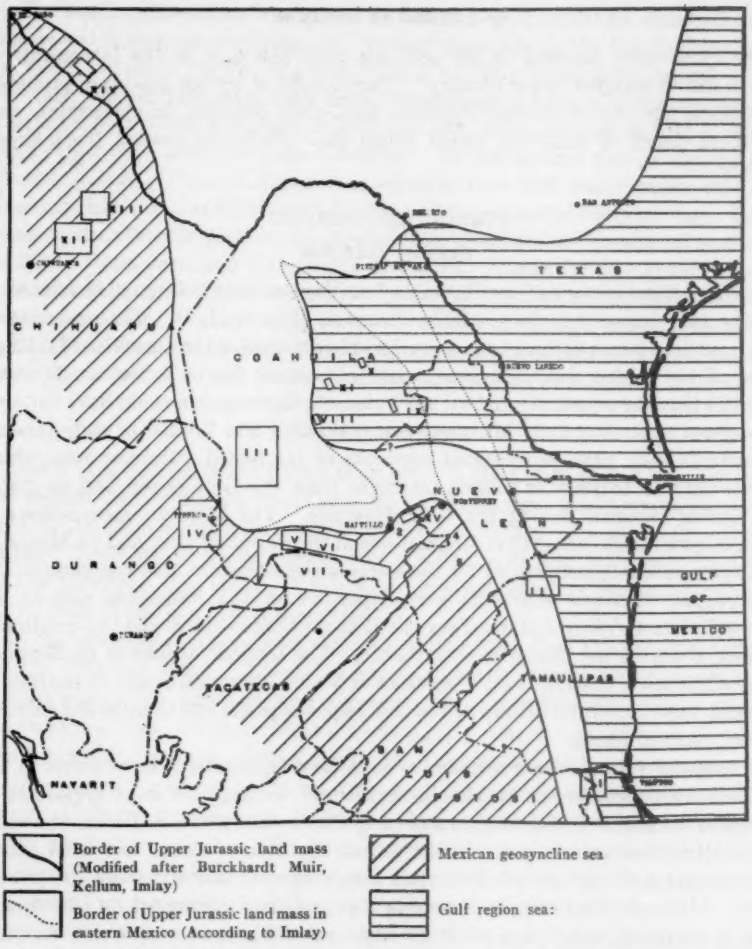


FIGURE 2.—*Upper Jurassic paleogeography of northeastern Mexico*

1. Santa Catarina 2. Roca de Arteaga. 3. Ramos Arizpe. 4. Santiago. 5. Cerro Potosi

I Tampico area (Sierra Madre Oriental)
II Sierra de San Carlos
III Acatita-Las Delicias area
IV Mountains west of Laguna district
V Western part, Sierra de Parras
VI Middle Part, Sierra de Parras
VII Melchor Ocampo area
VIII Sierra de San Marcos, east-central Coahuila
IX Sierra Azul, east-central Coahuila
X Potero de Oballos, east-central Coahuila
XI Potrero de Menchaca, east-central Coahuila
XII Placer de Guadalupe area, Rio Conchos Valley
XIII Cuchillo Parado area, Rio Conchos Valley
XIV Malone Mountains
XV Sierra de los Muertos area

coincides approximately with the boundary between land and sea in late Jurassic time. Imlay's reconstructions (1943b, Figs. 13–14), based on a study of sedimentary facies and paleogeography, show the position of the borders of the late Jurassic

land masses in northern Mexico. There would seem to be little evidence for projecting the narrow peninsula of eastern Mexico directly north from Monterrey to Del Rio, Texas, that would not be equally well explained in the modification of Imlay's figure which is here presented (Fig. 2). Between Monterrey and Saltillo, as has been demonstrated by Böse (1923b, p. 326) and mentioned by King (1942, p. 397), the northwest strike of the Sierra Madre Oriental turns sharply west-southwest from Monterrey in a series of closely packed arcuate folds convex northward. Böse stated that the individual folds plunge westward into the Parras Basin and that the only influence of the north Mexico Jurassic continent on the tectonics was "... by offering less thickness against lateral pressure because of the lesser thickness of the Mesozoic strata." He believed further that "... overfolding toward the north may be caused by the original lower positions of the country north of the Sierra de Parras." King following Kellum, Kane, and Imlay, stated that the folds were "... wrapped around the opposing buttress of the Coahuila Peninsula." The folds do tend to plunge somewhat into the Parras Basin, but their strike also curves sharply south near Saltillo and then west once more along the south side of the Parras Basin. The writer believes the arcuate folds between Monterrey and Saltillo reflect the buttressing effect of a re-entrant in the southern margin of the Coahuila Peninsula in Jurassic time. The site of the northernmost line of overfolding which brings pre-Upper Cretaceous rocks to the surface (Los Muertos anticline) is believed to coincide approximately with the late Jurassic shore lines in the Monterrey-Saltillo region.

The folds of the Sierra Madre Oriental northeast of Saltillo are elongate, closely packed, and generally overfolded toward the north. They commonly exhibit fan structures in cross section. Their tectonics has been discussed by Böse (1923b, pt. III) who presented a series of small-scale, north-south section sketches showing the generalized structural relations. Böse remarked on the notable lack of large throw faults and the absence of thrusting in a region characterized by the extreme deformation of its folds. He pointed out the development of what he called "periclinal folds" or large elongate brachy-anticlinal domes (*e.g.*, Sierra de La Mitra and Sierra de La Silla near Monterrey) and related them to the abrupt change in regional strike. He further indicated that the plunge westward toward the Parras Basin of most? of the folds was related to a north-south line of westward overfolding passing through Ramos Arizpe, Coahuila. The writer believes that Böse's "north-south line of western overfolding" is only a sharp curve in strike of the folds to the south near Saltillo. This change in strike reflects a southern extension of the late Jurassic land mass over what in Upper Cretaceous time became the Parras Basin. Plunging of the western ends of the folds is accompanied usually by a change in strike to the south or by a strong decrease in intensity of folding westward into the Parras Basin. The sharp Las Escaleras syncline of the mapped area continues to the west greatly flattened as the high synclinal mass of Upper Cretaceous beds in the Mesa de Guajardo, but the succeeding San Lucas anticline and others to the south show a sharp southward curving of their axes. Baker (1941) has estimated that the close folding between the latitude of Monterrey and the Cerro El Potosi (about 50 miles from north to south) involves a crustal shortening of about 50 per

cent. The mechanics of the stresses which folded the Mexican geosyncline are not known, but the compressional forces seem to have been directed from the west and southwest. The late Jurassic continent appears to have been narrowest to the south and because of its lesser mass might have transmitted the forces from the west to produce the northwest-trending folds north of Monterrey. The asymmetry of some of those structures (San Marcos, Menchaca) which exhibit steeper west flanks might be explained as a result of underthrusting of the eastern margin of the Coahuila Peninsula rather than Laramide stresses acting from east to west which were obviously inoperative farther north in the same trough in the Gulf region of the United States. Imlay (1937, p. 628) has suggested that at the time of deformation, the Lower Cretaceous rocks were covered by great thicknesses of younger sediments.

LOCAL FEATURES

General statement.—Anticlines and synclines (Pl. 1) are believed to represent the general structure between Monterrey and Saltillo. The geologic map (Pl. 1) shows the western terminations of the northernmost folds in the Lower Cretaceous and older rocks. The western ends of the folds are symmetrical or have slightly steeper north flanks. They plunge as high as 35°. Increase in curve of strike to the south near Saltillo is indicated by a comparison of the two largest anticlines. The western end of the Los Muertos anticlinal axis trends S. 70° W. whereas the axis of the San Lucas anticline trends S. 55° W. To the east, the major folds become closely packed and complicated by the development of infolded synclines. The anticlines become overturned or doubly recumbent to the north. Thrusting was noted only in the Potrerillos area of the Sierra de San Lucas, but a great deal of interbed and interformational sliding was seen especially on the north flanks of the anticlines. Cross faults involving minor displacements in the Lower Cretaceous rocks coincide with some of the north-south canyons in the area. These features are tear faults or zones of fracture which commonly mark the boundaries between overturned salients of the flanks and adjoining flank areas in which the dips are normal. Probably the zones of stretching and tear faulting were more pronounced in Upper Cretaceous strata since removed by erosion. The position of the present transverse canyons has probably been inherited from drainages developed in the fracture zones at some higher erosional level.

Folds.—The Los Muertos anticline, the northernmost fold in the area, brings up rocks older than the Upper Cretaceous. It is almost symmetrical where it plunges westward beneath the alluvium about 10 miles northeast of Ramos Arizpe. Both mountainous flanks are there composed of Aurora limestone, the northern range being known as the Sierra de Las Boquillas de Santo Toribio, the ridge composing the south flank as the Sierra del Caporal or the Sierra del Rancho. To the east the anticline widens rapidly toward the Cañón de Las Palomas. The north flank becomes vertical and overturned just south of Ojo Caliente in the Rincón de San Gregorio where two minor dip reversals bring the Cupido limestone to the surface. The south flank exhibits relatively gentle dips and is essentially a dip slope of Aurora limestone from the end of the range east to Puerto Las Palomas. Between

Cañón de Los Pinos and Cañón de Las Palomas the north flank is composed of steeply dipping Aurora and Cupido limestones, and the Taraises formation is exposed in the core of the fold along the Cañón de Los Pinos. Las Palomas canyon has been excavated in a wide zone of transverse faulting, along which the east wall of the canyon has moved relatively up and to the north. East of Cañón de Las Palomas the rugged north flank of the anticline,—the Sierra de Los Muertos—is composed of Cuesta del Cura, Aurora, and Cupido formations. Between the canyons of Las Palomas and Las Cortinas it is largely overturned and has been cut through by three smaller north-south canyons. The east wall of each of those canyons shows Lower Cretaceous beds strongly overturned to the north, whereas the strata on the west walls dip steeply north or are only slightly overfolded. It may be inferred that the canyons mark the sites of vertical, north-striking, stretch zones or tear faults along which the east sides have moved relatively north. East of Las Palomas canyon the core of the Los Muertos anticline is composed of Upper Jurassic Zuloaga and La Casita formations. The anticline continues far to the east, passing south of Santa Catarina, Nuevo León, where the north flank is vertical and composed of Aurora and Cupido limestones. Near Monterrey the axis curves to the southeast, and the fold continues at least as far as Villa Santiago where the northeast flank is overturned and composed of Lower Cretaceous limestones (Böse, 1923b, Fig. 2).

Near Puerto Las Palomas a terrace is developed in Aurora limestones on the south flank of the Los Muertos anticline. East of the Cañón de Las Sabanillas it passes into a minor syncline in which the La Peña formation is preserved. This infold widens to the east and passes into the lofty synclinal mountain named Sierra de La Calle. It has an elevation of nearly 9000 feet and is capped by the resistant Cupido limestones. The infolding of the La Calle syncline gives rise to the south to the corresponding San Blas anticline. Near the Cañón de Salitrillos, the south flank of the San Blas anticline dips steeply south, but to the east it becomes vertical, and the youngest beds exposed are overturned to the south. On the west side of the Cañón de Los Placeres, the south flank is recumbent, whereas in the east wall of the canyon the strata are vertical or dip steeply south. In the easternmost tributary to Cañón Placeres the lower massive Taraises limestones are offset at two places by transverse tear faults of small displacement, alone which the west side has moved relatively south. East of Rancho de Los Barreros, the core of the San Blas anticline consists of nearly vertical strata of the upper member of the La Casita formation.

Bordering the south flanks of the San Blas and Los Muertos anticlines is the synclinal Cañón de La Escalera. East of the Mesa de San Antonio the Escalera canyon ranges in width from 2 to 4 miles and is bounded on the south by the Las Clavellinas anticline. In that area the syncline is made up of the shales and limestones of the Indidura and Parras formations and is probably isoclinal. West of the Mesa de San Antonio the canyon merges with the synclinal valley of the Cañón de Las Maravillas and has a width of 7 to 10 miles. Exposures are uncommon in this wide, alluvium-covered valley, but it is doubtful if rocks younger than the Parras shale are preserved in the Las Escaleras syncline in this area.

The Clavellinas anticline is asymmetrical with steeper dips to the north, but it is not recumbent in the area mapped. It forms a low range which emerges from the

alluvium of the Cañón de Las Escalera due south of the Mesa de San Antonio. The western end of the range is known as the Cerro de Enmedio, and there the fold plunges about 35°. To the east in the Puerto de La Cuesta the anticline is dissected by arroyos draining the Las Maravillas canyon. East of the Puerto the fold increases rapidly in height and width and is known as the Sierra de Las Clavellinas. This range is largely thick-bedded Aurora limestones, but the overlying Cuesta del Cura formation crops out on the lower slopes of the Cerro de Enmedio and in the small hill of the Cerrito del Muerto, just south of Puerto de La Cuesta.

The Las Maravillas canyon follows a tightly folded syncline of Cuesta del Cura and Indidura formations which unites to the west with the syncline of the Cañón de La Escalera.

Bordering the canyons of Las Maravillas and La Escalera on the south is the San Lucas anticline, recumbent to the north. Its western end is only moderately asymmetrical where it terminates abruptly southwest of the Congregación de San Lucas, plunging S. 50° W. at about 35° beneath the alluvium. To the south the fold is bounded by the sharp syncline of Rincón de Las Vallas. To the east the north flank of the San Lucas anticline becomes vertical and then recumbent. It continues strongly overturned to near the eastern border of the mapped area, being composed largely of Lower Cretaceous limestones which dip southward as low as 35°. The mountainous ridge of the south flank constitutes the highest part of the Sierra de San Lucas and is a relatively gentle dip slope of Aurora limestones which dip 25°–35° S. From the Cañón de La Mina east to the Rincón de Potrerillos the axial plane of the fold dips about 45° S., and the core is composed of Taraises and upper La Casita formations. In the Rincón de Potrerillos the upper La Casita beds are secondarily folded and thrust over the Lower Cretaceous Taraises formation. East from Rincón de Potrerillos the north flank continues strongly overfolded to the north. The canyon leading to the Puerto del Jardín appears to be excavated along a north-south zone of fracturing. Lower Cretaceous limestones on the east wall of the canyon are vertical. Those on the west wall dip 35°–40° S. and have moved relatively to the north.

Faults.—Although faults in the area are of minor importance compared to the folds, they are by no means uncommon. They are ordinarily of small displacement, and most of them are transverse tear faults, related to the dominant overfolding of the anticlinal flanks. One such fault, probably vertical, just south of Ojo Caliente on the north flank of the Los Muertos anticline is mapped (Pl. 1). There, the outcrop belt of the La Peña, Aurora, and Cuesta del Cura formations is offset along a northwest-southeast line. Warm sulphurous carbonate waters ascend along the fault zone and have cemented the fault breccia and talus with caliche. The breccia stands out in a spur of considerable relief extending north toward the national highway near Los Banos. The east side of the fault has moved relatively north with a displacement of probably not more than 150 feet.

The large fault along the Cañón de Las Palomas trends slightly west of north. The east side of the fault has moved relatively up and north. On the basis of relative position of the lower limestones of the Taraises formation on each side of the canyon,

TABLE 3.—*Summary of geologic events*

STANDARD SECTION			SIERRA DE LOS MUERTOS AREA	COLUMNAR SECTION	SUMMARY OF GEOLOGIC EVENTS
UPPER CRETACEOUS	CAMPANIAN		PAUAS SHALE 4500'+		EMERGENCE OF EMERGING LAND MASSES IN WESTERN MEXICO FURNISHES LARGE AMOUNTS OF BLACK CARBONACEOUS MUDS WITH THIN LIME LENSES INTO SHALLOW, RESTRICTED SEAS. OCCASIONAL DEPOSITION OF GYPSIFEROUS CLAYS AND THIN LENSES OF GYPSUM.
	SANTONIAN				
	CONIACIAN				
	TURONIAN		INDIDURA FORMATION 1800'+		CONSIDERABLE INFLUX OF FINE CLASTICS AND SOME SANDS INTO MEXICAN GEOSYNCLINE, ALTERNATING WITH DEPOSITION OF LIME MUDS IN RELATIVELY SHALLOW WATERS.
	CENOMANIAN				
LOWER CRETACEOUS	ALBIAN		CUESTA DEL CURA FORMATION 400' - 500'		DEEPENING OF SEAWAYS. MODERATELY DEEP WATER DEPOSITION OF CHERTS AND PURE LIME OOZES WITH SOME CLAY.
			AURORA LIMESTONE 1000' - 1500'		SHALLOWING OF SEAS WITH DEPOSITION OF ORGANIC LIME OOZES AND CHERT IN RUDISTID REEFS. PROBABLE COMPLETE SUBMERGENCE OF COAHUILA PENINSULA.
	APTIAN	GARGASIAN	LA PENA FORMATION 25' - 135'		DEEPENING OF SEAS AND CONTINUED SUBMERGENCE OF COAHUILA PENINSULA. DEPOSITION OF CALCAREOUS MUDS AND CLAYEY LIME OOZES.
		BEDOULIAN			
	NEOCOMIAN	BARREMIAN	CUPIDO FORMATION 2000' - 2500'		MODERATELY DEEP WATER DEPOSITION OF CLAY AND PURE LIME OOZES. FOLLOWED BY SHALLOWING OF WATERS WITH DEPOSITION OF RUDISTID REEFS AND CHERT.
		HAUTERIVIAN	TAMAULIPAS FORMATION 850'+		DEPOSITION OF REEF LIMESTONES FRINGING LAND MASSES FOLLOWED BY SUBMERGENCE OF LOW COAST AND TRANSGRESSION OF SEAWAYS NORTHWARD OVER COAHUILA PENINSULA. DEPOSITION OF CALCAREOUS MUDS AND OFFSHORE LIMESTONES.
		VALANGINIAN			
		BERRIASIAN			
UPPER JURASSIC	TITHONIAN		LA CASITA FORMATION — UPPER MEMBER 1200'±		POSITIVE MOVEMENTS OF COAHUILA PENINSULA. COAST LINES RUGGED. PROBABLY SOME SOUTHWARD RETREAT OF SEAS WITH DEPOSITION OF SANDSTONES, CONGLOMERATES, AND SANDY REEF LIMESTONES.
	PORTLANDIAN				
	KIMMERIDGIAN		LOWER MEMBER 1000'±		ADVANCE OF SEA OVER LOW COAST. DEPOSITION OF CARBONACEOUS AND SANDY MUDS WITH SOME THIN LENSES OF LIME OOZES. SEDIMENTS LAID DOWN NOT FAR FROM SHORE.
	OXFORDIAN		ZULOAGA FORMATION 300'+		SHALLOW SEAS WITH DEPOSITION OF REEF LIMESTONES FOLLOWED BY LAGOONAL CONDITIONS AND RETREAT OF SEAS TO SOUTH.

a displacement of about 1000 feet is inferred. It is the writer's belief that the gypsum exposed in the floor of the canyon has been squeezed up along the plane of this transverse fault.

In the Rincón de Potrerillos, west of Picacho de Los Galapitos, several minor thrust faults were observed where the eastern extension of the syncline of Rincón de Las Vallas has been shoved northward over the San Lucas anticline. The thrusts are of small displacement, die out rapidly along the strike, and their planes dip very gently to the south. Three of them were observed in an imbricate pattern along the Cañón de Los Terreros. In the northernmost of the three, sandstones of the upper member of the La Casita formation have ridden north a short distance over medium-bedded limestones considered to belong to the Taraises formation. The fault plane is marked by a 1½-foot band of gouge material, and it dips about 10° S. The other two thrusts are smaller, and in them only La Casita sediments are involved. To the west these three faults merge into one almost horizontal thrust seen in the upper reaches of the Cañón de Los Bueyes, southeast of the Picacho de Los Galapitos. There the fault is in shales of the La Casita formation, and farther west it seems to pass into a fold on the north limb of the Rincón de Las Vallas syncline.

MINERAL DEPOSITS

The geology of the ore deposits in the Sierra de Los Muertos area was not investigated during the present study. The location of a few of the now mostly depleted mines is shown on Plate 1.

Most of the mineralization seen in the area is replacement deposits of lead-zinc carbonates that have probably resulted from redeposition by solutions escaping from oxidized ore bodies. Triplett and Burbridge (1941) have discussed the characteristics of the carbonate concentrations in the Monterrey District. The ore bodies are found in porous dolomites in the lower part of the Cupido formation as well as in zones of secondary dolomitization in the limestones of the Zuloaga formation. They commonly occur at the intersection of transverse faults with the axes of anticlinal folds. Common ore minerals are smithsonite, cerussite, calamine, and hydrozincite.

SUMMARY OF GEOLOGIC HISTORY

Table 3 shows a somewhat detailed columnar section and summarizes the geologic events in the Sierra de Los Muertos area.

SYSTEMATIC PALEONTOLOGY

Phylum MOLLUSCA

Class CEPHALOPODA

Order NAUTILOIDEA

Family CYMATOCERATIDAE Spath, 1927

Genus *Paracymatoceras* Spath, 1927

GENOTYPE: *Nautilus asper* OPPEL, in ZITTEL, Stramberger Schichten, pl. III, fig. 1, 1868.

Paracymatoceras milleri Humphrey n. sp.

(Plate 4, figure 1; Plate 5, figures 1, 2)

DESCRIPTION: This species is represented by one fairly complete and moderately well preserved specimen which has been somewhat compressed.

Shell involute, discoidal, compressed. Whorl section much higher than wide; subtrapezoidal in outline; thickest in lower third. Flanks flattened; venter narrowly rounded in youth, flattened convex on anterior part of outer whorl. Umbilicus small, less than one-sixth greatest diameter of conch; umbilical shoulder rounded, indistinct; umbilical wall low, inclined.

Surface of shell marked by prominent transverse ribs that begin on umbilical wall and are almost straight across lower two-thirds of flanks, curving sharply backward on upper third of lateral zones to form deep, narrowly rounded ventral sinus. Some ribs split into two equal branches just below middle of flanks. Neither suture lines nor position of siphuncle observed on holotype.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 15886.....	127	70	47	20±

REMARKS: This species is named in honor of A. K. Miller of Iowa City, Iowa, whose numerous writings have contributed much to the knowledge of the Nautiloidea.

The holotype (U. M. 15886) was examined by Miller, who confirmed the writer's determination of the specimen as belonging to *Paracymatoceras* and suggested (letter of April 23, 1947) that the form might be properly referred to *Paracymatoceras texanum* (Shumard) (1860, p. 590). The writer believes, however, that there are certain differences between the present example from the upper Aptian of northern Mexico and Shumard's species from the Washita of Texas that justify giving a new trivial name to the Mexican form.

P. milleri Humphrey has a narrower umbilicus, and the whorl section is less inflated than in *P. texanum* (Shumard). In Shumard's species the ribs curve convex forward on the upper third of the lateral zones before curving posteriorly in a ventral sinus. In the present example the ribs curve convex backward across the venter after having been directly transverse across the lower two-thirds of the flanks. Further, the venter on the anterior part of the outer whorl in the new species is more broadly rounded than in *P. texanum* (Shumard), judging from the form figured by Miller and Harris (1945, pl. V, fig. 2).

DEPOSITORY: Holotype U. M. 15886 in the Universty of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Puerto de San Isidro, Sierra de Mapimí, Durango, Mexico. Collected by L. B. Kellum and T. S. Jones.

Order AMMONOIDEA

Family PARAHOPLITIDAE Spath 1922

Genus *Dufrenoya* (Burckhardt Ms.) Kilian and Reboul 1915

1915 *Parahoplites* (= *Dufrenoyia* Burckhardt) KILIAN AND REBOUL, Montelimar, pp. 34, 35, 37.
1915 *Parahoplites* (*Dufrenoya*) KILIAN AND REBOUL, Montelimar, pp. 178, 196, 198, 199, 203, 205, 207.
1922 *Stenhoplites* SPATH, Angola, p. 110.
1923 *Dufrenoyia* SPATH, Summary of Progress 1922, p. 147.
1923 *Stenhoplites* SPATH, Summary of Progress 1922, p. 147 (footnote).
1925 *Dufrenoya* BURCKHARDT, Río Nazas, p. 115.
1930 *Dufrenoyia* SPATH, Lower Greensand, p. 437.
1938 *Stenhoplites* ROMAN, Les Ammonites, p. 347.
1940 *Dufrenoya* SCOTT, Cretaceous Cephalopods, p. 1021.

GENOTYPE: *Ammonites dufrenoyi* D'ORBIGNY, Pal. Fr. Terr. Cret., I, p. 200, pl. 33, figs. 4–6, 1840–41.

Previous to publication of the generic name *Dufrenoyia* (= *Dufrenoya* Burckhardt MS.) by Kilian and Reboul in 1915, forms now generally assigned to *Dufrenoya* had been variously referred to such genera as *Hoplites*, *Parahoplites*, and *Neocomites*. Misidentification of *Ammonites furcatus* Sowerby, by Kilian, Jacob, Pictet, Corroy, Roch, and others, with *Ammonites dufrenoyi* d'Orbigny resulted in

the adoption by Jacob and Kilian of an upper Aptian "*furcatus*" zone after Sowerby's species, which is now considered to be restricted to the *deshayesi* zone of the upper Bedoulian (lower Aptian). In 1922, Spath (p. 110) pointed out the error of confusing D'Orbigny's and Sowerby's species and proposed the name *Stenhoplites* for the group of *Hoplites furcatus* Kilian *non* Sowerby, naming as genotype *Ammonites dufrenoyi* D'Orbigny. In 1923, Spath (p. 147) rejected the "*furcatus*" zone of Kilian and Jacob and abandoned the name *Stenhoplites* as synonymous with *Dufrenoya*, at the same time suggesting, "It may be adviseable to retain the genus *Stenhoplites* for *A. furcatus* Sowerby, quite distinct from *D. dufrenoyi* (D'Orbigny) and of pre-*deshayesi* age."[1] In 1925, Burckhardt's manuscript, completed in 1911 and cited by Kilian and Reboul in 1915, was published, defining the genus *Dufrenoya* and referring to it 11 species, one of them as new. The genus was named by Burckhardt for the "group of *Amm. dufrenoyi*", D'Orbigny's species subsequently being cited by Scott (p. 1021) as the genotype. In 1930, Spath abandoned the name *Stenhoplites*, since he believed that *D. truncata* Spath was sufficiently close to forms with ribbed venters in the British Museum identified as *D. dufrenoyi* (D'Orbigny) to made it "unnecessary to adopt a separate generic name ('*Stenhoplites*', Spath 1922) for the *furcatus* group." D'Orbigny, in his original description of *Ammonites dufrenoyi*, stated that the venter of his species was smooth (*i.e.*, unribbed), an observation reinforced by the writer's examination of a suite of *D. dufrenoyi* (D'Orbigny) from the Gargasian (upper Aptian) of Carniol, Basses-Alpes, France. The Carniol examples show unribbed venters to a greatest diameter of 42 mm., and the ribbed forms in the British Museum may represent unrecognized French forms near *Dufrenoya justinae* (Hill) or similarly ornamented species which occur with *D. dufrenoyi* (D'Orbigny) in the upper Aptian of Mexico. If such should prove to be the case, it might be desirable to reinstate the term *Stenhoplites* Spath (1923, p. 147, footnote, *non* 1922, p. 110) or to give another name to a group including *D. furcatus* (Sowerby), *D. justinae* (Hill), *D. steubeli* (Gerhardt), *D. ebosei* n. sp., and other forms with bifurcating ribs and transversely ribbed venters.

Strict adherence to the International Rules for Zoological Nomenclature would doubtless result in *Ammonites furcatus* Sowerby (cited in Kilian and Reboul, 1915, p. 34) being taken as the type of the genus *Dufrenoyia* (Burckhardt Ms.) Kilian and Reboul, while *Stenhoplites* Spath (1922, p. 110) would have as genotype, *Ammonites dufrenoyi* D'Orbigny. In the present paper, however, the writer is following precedent set by Spath in 1923 (p. 147, footnote) and again in 1930 (p. 437 and footnote) and by Scott in 1940 (p. 1022) in considering *Ammonites dufrenoyi* D'Orbigny as the type of the genus *Dufrenoya*.

A literal translation of Burckhardt's original delineation of *Dufrenoya* (1925, p. 115) follows:

"Shell discoidal, flattened, compressed, involute, or a little evolute. Transverse section oval or elongate oval, somewhat more slender toward the venter. Venter truncated, flattened, forming well marked angles with the flanks. Flexuous costae, generally narrow, cover the flanks, widen toward the venter and form an inflection directed forward on the middle of the flanks, being somewhat falciform and inflected backward on the external part of the flanks. The flanks of the adult are ornamented with large principal costae and small intercalated costae which are generally simple and alternate with more or less regularity. The principal costae rise in the umbilical region, the intercalated ones toward the lower third or the middle of the flanks, also occasionally still lower. Sometimes there is no regular alternation of the costae, in which case various principal or intercalated costae may follow. In some forms a not always clear bifurcation of the costae is observed toward the middle of the flanks. Such bifurcation also exists in the youthful stage and then the costae may form sickles, two of them joining in the umbilical region by means of light, tuberculiform swellings that may be observed on the umbilical border. The costae form denticulate marginal tubercles on the angles, between the venter and the flanks. Between such pairs of tubercles, the venter is either smooth or else it is crossed by the costae. The majority of the species appear to have a smooth venter in youth, the costae later passing over the venter in a more or less marked manner. Sometimes, far from being attenuated, the costae are very prominent and marked on passing over the venter (for example in *Dufrenoya texana* nob.). The suture line is only known in any detail from *Dufrenoya dufrenoyi* d'Orb. sp. (see the suture published by Sarasin, Genres Hoplites, etc., 1 c., p. 769, fig. 6 in the text) and from *Dufrenoya hopliloides Lasswitz sp.* (Kreideammoniten von Texas, 1. c., p. 4, fig. 4 in the text) (1). Saddles and lobes little incised, relatively simple. External lobe shorter than the first lateral lobe; the latter almost symmetrical, with three well-developed, principal branches. Second lateral lobe much smaller than the first, asymmetrical because the principal external lateral branch issues from higher on the trunk than does the internal one. One or two scarcely oblique and very small

[1] Corrected in 1930 by Spath (p. 437) to read "pre-*dufrenoyi* age."

auxiliary lobes. External saddle very wide, not contracted at the base, divided into two almost equal parts by a short secondary lobe. First lateral saddle half the width of the external saddle, asymmetrically divided in two unequal branches, of which the internal one is the largest. Second lateral saddle very low and wide, divided in two almost equal parts; its height does not exceed half the height of the first lateral saddle. The species of the genus *Dufrenoya* characterize the upper Aptian, a few being also cited from the lower Aptian."

Scott (1940, p. 1022), in his discussion of the generic characters of *Dufrenoya*, stated, "On early whorls costae . . . cross the venter with little or no attenuation." Burckhardt, on the contrary, stressed the smoothness of the venter in the young stages of the majority of species. Scott's observation seems to have validity only in *D. justinae* (Hill) and perhaps in *D. bösei* Humphrey n. sp., *D. furcata* (Sowerby), and *D. steubeli* (Gerhardt). *D. dufrenoyi* (D'Orbigny) has a smooth venter in youth, as do also *D. lurensis* (Kilian), *D. codazziana* (Karsten), *D. stenzeli* Humphrey n. sp., and *D. scotti* Humphrey n. sp. Whatever change may be observed in the development of the venter seems to be one of early smoothness in youth followed by the acquisition of ribbing in adult stages. There may be thus a suggestion that the group of *dufrenoyi* may have been derived from much different ancestors (Neocomitidae?) than was the *furcatus* group (Hemihoplitidae?).

The following species were assigned by Burckhardt (1925, p. 17) to *Dufrenoya*:

D. dufrenoyi (d'Orbigny)
D. furcata (Sowerby)
D. lurensis (Kilian)
D. cfr. *furcata* (Sowerby) Sinzow sp.
D. texana Burckhardt
D. justinae (Hill)
D. roemeri (Cragin)
D. hoplitoides (Lasswitz)
D. aff. *dufrenoyi* (d'Orbigny) Burckhardt sp.
D. codazziana (Karsten)
D. steubeli (Gerhardt)
D. somalica Mayer-Eymar)

Of these, Scott (1940, p. 971, 1022–23) showed that *D. roemeri* (Cragin) and *D. texana* Burckhardt were synonyms of *D. justinae* (Hill) and cited Adkins' reference (1933, p. 399–400) of *D. hoplitoides* (Lasswitz) to *Mantelliceras* and demonstrated that, in any case, Lasswitz' species could not possibly belong to *Dufrenoya*. *D. dufrenoyi* (D'Orbigny) and *D. lurensis* (Kilian) are discussed herein under the description of Mexican species of the genus, as is *D. justinae* (Hill). *D.* aff. *dufrenoyi* (D'Orbigny) Burckhardt sp. is here referred tentatively to *D. codazziana* (Karsten), which is considered a valid representative of the *dufrenoyi* group from Colombia. *D. steubeli* (Gerhardt) is not unlike *D. furcata* (Sowerby) and may indicate a late Bedoulian age for the beds in which it occurs. *D. somalica* (Mayer-Eymar) is quite distinct from all species of *Dufrenoya* by the character of its ribbing and its neocomitid-like venter and should be referred to another genus. *D. furcata* (Sowerby) is somewhat inflated with a strongly ribbed venter, and Burckhardt's figure of a cast of the holotype (1925, pl. X, figs. 12–13) suggests that the ribs may bifurcate. It occurs in the Lower Greensand of England (upper *deshayesi* zone) and probably in the upper Bedoulian of France. Its relationships have been briefly noted above. According to Kilian and Reboul (1915, p. 34), *D.* cf. *furcata* (Sowerby) Sinzow sp. is distinct from *Hoplites furcatus* (= *dufrenoyi* D'Orbigny) Kilian *non* Sowerby, but closely related to it. From Sinzow's figure (1909, pl. I, figs. 5–6) his species would seem to belong to the *dufrenoyi* group and to be possibly conspecific with D'Orbigny's species.

Since 1925, only four species have been assigned to *Dufrenoya*, as far as is known to the writer. Spath (1930, p. 436) described *D. truncata* Spath as new from the Lower Greensand (upper Bedoulian-upper *deshayesi* zone) of England. *D. truncata* Spath is characterized by an early *Deshayesites*-like stage, after which the venter becomes flattened and transversely ribbed. In 1940, Scott described two new species from the Trinity group of Texas which he referred to *Dufrenoya* and, at the same time (p. 971), proposed the new name *Dufrenoya burckhardti* Scott for the Mexican examples illustrated by Burckhardt (1925, pl. IX, figs. 7–9) as *D. texana* Burckhardt. In this paper, *D. burckhardti* Scott is considered synonymous with *D. justinae* (Hill). The first of Scott's new species, "*Dufrenoya*" *robusta* Scott (1940, p. 1025, pl. LXIII, figs. 8–9), has little in common with *Dufrenoya* but on the other hand shows many of the characters of *Colombiceras* Spath, to which genus it is here referred. The second new form, "*Dufrenoya*" *comalensis* Scott (1940, p. 1026, pl. LX, figs. 4–5), has almost radial ribs and shows neither the venter of a typical *Dufrenoya* nor the clavate ventro-lateral tubercles common to all species of that genus. It is here referred to *Parahoplites* with question.

Ten species, five of them new, are here described and referred to *Dufrenoya*. These forms occur in the La Peña formation or in its stratigraphic equivalents in northern Mexico. In Europe, species of *Dufrenoya* are especially characteristic of the Gargasian (upper Aptian, zone of *martinii*) of France and are present in the upper Bedoulian (lower Aptian, zone of *deshayesi*) of England.

Dufrenoya justinae (Hill)

(Plate 6, figures 1–7; Plate 7, figures 1–9)

1893 (June 3) *Acanthoceras? justinae* HILL, Paleontology of the Trinity division, p. 38, pl. VII, figs. 1–3.
1893 (June 11) *Hoplites roemeri* CRAGIN, Contribution to the Invertebrate Paleontology, p. 234, p. XLIV, figs. 4–5.
1901 *Ammonites justinae* HILL, Black and Grand Prairies, pl. XXI, fig. 6.
1902 *Hoplites furcatus* (Sowerby), KILIAN, Sur quelques gisements de l'etage aptien, p. 358.
1904 *Hoplites furcatus* (Sowerby), KILIAN *in* LASSWITZ, Kreide-ammoniten von Texas, p. 4, text fig. 1.
1925 *Dufrenoya justinae* (Hill), BURCKHARDT, Río Nazas, p. 17, pl. X, figs. 14–15.
1925 *Dufrenoya texana* BURCKHARDT, Río Nazas, p. 20, pl. IX, figs. 2–15.
1927 *Dufrenoya texana* Burckhardt, BÖSE AND CAVINS, Southern Texas and Northern Mexico, p. 21 and footnote.
1937 *Dufrenoya texana* Burckhardt, RIEDEL, Amonitas del cretacico inferior, pp. 48–49, pl. VII, figs. 15–19, pl. XIV, fig. 25.
1940 *Dufrenoya burckhardti* SCOTT, Cretaceous Cephalopods, p. 971.
1940 *Dufrenoya justinae* (Hill), SCOTT, Cretaceous Cephalopods, pp. 1022–25, pl. LX, figs. 7–8, pl. LXII, fig. 9, text fig. 155.

In 1940, Scott showed that ammonites described by Cragin and Lasswitz, respectively, as *Hoplites roemeri* Cragin and *Hoplites furcatus* (Sowerby) were probably topotype specimens of *Dufrenoya justinae* (Hill) and that the names should disappear in synonymy before Hill's species. Scott also proposed the name *Dufrenoya burckhardti* Scott for Mexican forms previously considered by Burckhardt as conspecific with *Hoplites furcatus* (Sowerby) Lasswitz sp. Hundreds of examples of *Dufrenoya* from various northern Mexico localities, identical with the specimens from the Río Nazas Valley in Durango figured by Burckhardt as *Dufrenoya texana* Burckhardt, have been studied by the writer. They have been compared with topotype suites of *Dufrenoya justinae* (Hill), made available for study through the courtesy of the United States National Museum and the Texas Bureau of Economic Geology. The writer believes there is no difference between examples from the two areas that do not come within the very considerable range of variation of the species. *Dufrenoya burckhardti* Scott is here considered conspecific with *Dufrenoya justinae* (Hill), as are the Colombian forms described and identified by Riedel as *Dufrenoya texana* Burckhardt.

DESCRIPTION: The following observations are based on numerous whorl fragments and several more or less entire examples from Mexico, some of which are here figured for comparative purposes.

Form discoidal; compressed; whorls increasing rapidly in height, slowly in width, embracing about one-third of preceding whorls. Whorl section ellipsoidal, widest in lower third; flanks slightly convex below, flattened and inclined toward venter above. Umbilicus shallow, moderately narrow, about one third of diameter; umbilical wall oblique; umbilical shoulder moderately rounded. Venter truncated, flattened, pronounced ventro-lateral angles.

Shell marked by falciform, regularly alternating, primary and secondary ribs. Primaries begin at whorl suture or on umbilical wall, curve convex forward on lower third of flanks and are convex backward above, bending forward to form clavate tubercles on ventro-lateral angles. Secondary ribs rise below mid flanks and are equal in strength to primaries on upper third of whorl side. Rarely, two primaries or two secondaries may follow. Any suggestion of bifurcation is usually more apparent than real, a short rib occasionally dying out on the side of an adjoining primary. All ribs of equal prominence and evenly spaced on venter, which they cross transversely. In profile, ribs on venter are flattened or may be higher posteriorly and inclined forward, giving a "cog-wheel" appearance to the venter. Density of ribbing usually greater on young whorls, ribs becoming coarser and more separated with age, although rather evenly spaced. Width of ribs and interspaces subequal. Septal suture reproduced by Scott (1940, p. 1024, fig. 155). As in *Dufrenoya dufrenoyi*

(d'Orbigny) (*see* Sarasin, 1897, p. 769, fig. 6), trifid, almost symmetrical first lateral lobe is about twice as wide and much longer than ventral lobe.

One young form (U. M. 24245) from Rio Nazas shows flattened venter with faint transverse ribbing and bifurcation low on flanks at diameter of 8 mm. A whorl fragment (U. M. 22580) from Sierra de los Muertos, Coahuila, shows typically transversely ribbed and flattened venter at whorl height of 42 mm.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Hypotype U. M. 21852	80?	34	22	26.7
Hypotype U. M. 20206	60	30	18	20
Hypotype U. M. 24246	46	19	12	17
Hypotype U. M. 24008	39	19	9?	11
Hypotype U. M. 21876	26	10	?	8
Hypotype U. M. 22580	?	42	24?	?
Hypotype U. M. 21854	?	24	14	17?

REMARKS: This species is characterized especially by the relief and prominence of the ribbing across the squared venter. *Dufrenoya furcata* (Sowerby) has much coarser and less numerous ribs, and the shell of the British species is more inflated and has a wider venter. *Dufrenoya steubeli* (Gerhardt) seems to have a rather rounded venter, and its ornamentation appears to change radially on the anterior part of the outer whorl where the ribs are much more widely spaced than on the younger stages (*see* Burckhardt, 1925, pl. X, figs. 5–6). *Dufrenoya codazziana* (Karsten) has a generally finer costation than *Dufrenoya justinae* (Hill) and appears to have a smooth venter in its youthful stages.

DEPOSITORY: Hypotypes U. M. 20206, 21852, 21854, 21876, 22580, 24008, 24245, 24246, 24247, 24248, in the University of Michigan, Museum of Paleontology. Topotypes U. S. Nat. Mus. 104364a, b, c, in the collections of the United States National Museum, Washington, D. C.

OCCURRENCE: La Peña formation, Sierra de los Muertos, Coahuila and El Mulato Ranch, Rio Nazas, Durango. Upper member of La Peña formation, Sierra de Parras, Coahuila. Cow Creek member of the Travis Peak formation, western Travis County, Texas. Beds with *Cheloniceras* (Upper Aptian), Sierra de Bogota, Colombia.

Dufrenoya dufrenoyi (d'Orbigny)

(Plate 8, figures 1–6)

1840 *Ammonites dufrenoyi* d'ORBIGNY, Pal. Fr. Terr. Cret., p. 200, pl. XXXIII, figs. 4–6.
1849 *Ammonites dufrenoyi* d'Orbigny, QUENSTEDT, Die Petrefactenkunde Deutschlands, I, Cephalopoden, p. 158, pl. V, figs. 10a–b.
1888 *Hoplites furcatus* (I. Sow.), KILIAN, Provence, p. 682.
1910 *Hoplites (Neocomites) furcatus* (Sow.), KILIAN, Lethaea, Teil II, Bd. 3, Abt. 1, Lief. 2, pl. VIII, figs. 3a-b.
1915 *Parahoplites furcatus* Sow. (= *Dufrenoyia* Burckhardt), KILIAN AND REBOUL, Montelimar pp. 34–35, text figure 4.
1922 *Stenhoplites dufrenoyi* (d'Orb.), SPATH, Angola, p. 110.
1925 *Dufrenoya dufrenoyi* (d'Orb.), BURCKHARDT, Río Nazas, p. 17.

The following is a translation of d'Orbigny's original description of *Ammonites dufrenoyi* d'Orbigny.

"Shell suborbicular, very compressed, transversely ornamented per whorl by 27 to 36 long flexuous ribs, widening toward the periphery where each forms a weak tubercle. Of these ribs, some, alternatively, extend from the dorsum to the umbilical border, while the others occupy only the upper two-thirds of the whorl. Spire growing very rapidly, formed of compressed whorls with truncated dorsum (which is smooth), ornamented on each side by compressed paired tubercles, corresponding to the terminations of the ribs. In the umbilicus the whorls are exposed to about one-half of their height. The umbilicus is about 45/100 of the overall diameter. The aperture is very compressed,

narrowed forward, truncated above, forming the two angles. Sutures deeply incised, divided laterally in four lobes composed of unequal parts. Dorsal lobe as wide, but shorter than the upper lateral lobe, ornamented on each side by three branches, of which the lowest has four digitations. Dorsal saddle almost twice the width of the dorsal lobe, divided by an accessory lobe in two parts, themselves incised, being each divided in two. The upper lateral lobe a little more than half as wide as the dorsal saddle, formed of a single trunk adorned by five branches, of which the lower median one has nine digitations divided in three smaller branchlets. Lateral saddle about one half the width of the dorsal saddle, separated in two unequal parts, the lower being the largest. Lower lateral lobe and the two following lobes become less and less complicated, the same being true of the succeeding saddles. The upper part of the last suture shows a dorsal lobe with a small lateral lobe on each side."

In the translation, *dos* and *dorsale* are rendered as "dorsum" and "dorsal" which equal "venter" and "ventral" in modern terminology.

REVISED DESCRIPTION: The following observations are based on six specimens of *Dufrenoya dufrenoyi* (d'Orbigny) from the Gargasian of Carniol (Basses-Alpes), France, and made available for study by the writer through the courtesy of Dr. J. B. Reeside, Jr. of the United States National Museum. Five of these individuals were identified by W. Kilian as *Parahoplites furcatus* (Sowerby). The other was accompanied by a label in Kilian's handwriting identifying it as *Hoplites dufrenoyi* (d'Orbigny), showing that he probably considered the two names synonyms.

Form discoidal, compressed, whorls increasing rapidly in height, slowly in width; embracing preceding whorls by about one-half. Whorl section much higher than wide, thickest in lower third, flanks convex below, flattened and inclined toward venter above. Umbilicus shallow, moderately small; umbilical wall low, steeply inclined; umbilical shoulder strongly rounded. Venter truncate, flattened, may be slightly excavated.

Shell marked by regularly alternating, somewhat falciform primary and seconary ribs. Primaries begin on umbilical shoulder, are convex forward on lower flanks and convex backward on upper flanks; most prominent umbilically, widen and flatten toward venter and terminate in small, weakly clavate prominences on ventro-lateral angles. Secondaries rise near mid flanks; usually only one is intercalated between adjoining primaries. Venter typically smooth or marked by faint swellings between paired clavi. Simple suture line characterized by short ventral lobe and large, much longer and symmetrically trifid first lateral lobe.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Hypotype USNM 104363b	41.4	18.2	11	12.8
Hypotype USNM 104363c	22	10	6.7	6.3
Hypotype U. M. 21757	44.5	19.5	12	15
Hypotype U. M. 24249	31.5	14.8	9?	9?

REMARKS: Examples from northern Mexico compare very closely with the specimens at hand from the Gargasian of Carniol, France. The suture of the smaller Mexican example (Pl. 8, fig. 6) shows a ventral lobe exactly like that displayed by the French forms, but the remainder of the suture is poorly preserved. The larger specimen from Mexico (Pl. 8, figs. 3–4) shows a marked flattening of the ribs toward the venter, but the suite of forms from Carniol shows considerable variation in that respect.

DEPOSITORY: Hypotypes U.S.N.M. 104363b and 104363c, in the collections of the United States National Museum, Washington, D. C. Hypotypes U. M. 21757 and 24249 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: Upper Aptian marls of Gargas, near Apt (Vaucluse), and from Carniol (Basses-Alpes), France. Upper member of La Peña formation, Cuesta del Cura, Sierra de Parras, Coahuila. Locality 4I of Ralph W. Imlay.

Dufrenoya lurensis (Kilian)

(Plate 8, figures 7, 8, 12, 13)

1888 *Hoplites furcatus* Sowerby var. *lurensis* KILIAN, Mont. de Lure, p. 269.
1888 *Hoplites lurensis* KILIAN, Provence, p. 681, pl. XX, figs. 2a-b.

1913 *Parahoplites lurensis* KILIAN, Lethaea, pl. VIII, figs. 8a-b, pl. X, fig. 5.
1925 *Dufrenoya lurensis* (Kilian) BURCKHARDT, Río Nazas, p. 17.
1930 *Dufronoyia lurensis* (Kilian) SPATH, Lower Greensand, p. 436, pl. XV, fig. 4.

The following is a translation of Kilian's original description:

"Shell discoidal, whorls little embracing, being covered to a third of their height, ornamented by 19 simple ribs per whorl. These ribs are much accentuated, flexuous, widely spaced, starting on the border of the umbilicus, strongly marked on the middle of the flanks, then widening and terminating on the border of the siphonal region in accentuated tubercles. All of the ribs are directed forward on leaving the lower third of the flanks. In youth, all ribs do not extend to the umbilicus, one in two dying out on the middle of the flanks and seemingly attaching themselves to the adjoining rib. At a more advanced age, the ribs become still stronger, more widely spaced and the tubercles become more prominent.

"Flanks rounded, aperture of an hexagonal outline, having its greatest thickness at the middle of the flanks, only a little higher than wide.

"Sutures unknown."

REMARKS: Four more or less fragmentary examples in our collections from northern Mexico agree rather closely with Kilian's figures and description and are here considered conspecific with his species from the Gargasian (upper Aptian) of France. The ventro-lateral tubercles in the Mexican specimens are very large and prominent, narrowly clavate. The secondary ribs are rare and appear to begin on the lower third of the flanks. The primaries begin on the inclined umbilical wall, curve strongly forward on the lower third of the flanks, backward across mid flanks, and sharply forward again to the ventro-lateral margin. All ribs widen considerably on the upper third of the whorl sides and do not cross the venter, which is smooth or marked by low swellings between opposed clavi. The septal sutures are not shown in the Mexican examples.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype	41	?	?	14
Hypotype U. M. 24250	54	19.3	14?	18
Hypotype U. M. 24251	?	22.5	18	?

DEPOSITORY: Holotype in Sorbonne Collections, Paris. Hypotypes U. M. 24250, 24251 and 23963 in University of Michigan, Museum of Paleontology.

OCCURRENCE: Gargasian marls with *Dufrenoya dufrenoyi* (d'Orbigny) at Carniol (Basses-Alpes), France. La Peña formation, Puerto Las Palomas, Sierra de los Muertos, Coahuila.

Dufrenoya stenzeli Humphrey n. sp.

(Plate 8, figures 9–11)

DESCRIPTION: This species is represented by four specimens, well preserved as internal casts.

Form discoidal; much compressed; fairly evolute; whorls much higher than wide; embracing less than one-third of preceding whorls. Whorl section elongate-ellipsoidal, thickest in lower one-third, flanks flattened, inclined toward venter. Umbilicus shallow, rather narrow; umbilical wall abrupt, oblique; umbilical shoulder steeply rounded. Venter truncated, flattened, prominent vetro-lateral angles.

Shell marked by irregularly alternating primary and secondary ribs. Primaries begin near whorl suture and are prominent on umbilical shoulder; curve convex forward below and are convex backward on upper two-thirds of whorl sides. Two or three primaries may follow. One or two intercalated secondaries rise well down on lower third of flanks and are usually slightly less prominent above than are the primaries. All ribs incline sharply forward to terminate on ventro-lateral angles in well-developed, narrow, symmetrically paired clavi. Narrow venter smooth or marked by faint swellings between clavi, especially on younger whorls, but definitely not transversely ribbed. Interspaces wider than ribs. Suture line unknown.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 22540	54	23	11.3	14.3
Paratype U. M. 24252	47.7	21	9	14
Paratype U. M. 24253	38	16.4	7?	11
Paratype U. M. 24254	?	18	10	?

REMARKS: This species is very close to *Dufrenoya dufrenoyi* (d'Orbigny) but is distinguished from it in having much larger and more elongate ventro-lateral clavi and the primary ribs rise at the whorl suture instead of on the umbilical wall or shoulder, and in having slightly smaller whorl-height ratio. This species is named in honor of Henryk B. Stenzel of Austin, Texas.

DEPOSITORY: Holotype U. M. 22540 and Paratypes U. M. 24252, 24253, and 24254 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Cañón de San Antonio, Sierra de los Muertos, Coahuila.

Dufrenoya bösei Humphrey n. sp.

(Plate 9, figures 1, 2)

DESCRIPTION: The following observations are based on one fairly well preserved internal cast from near Rancho El Mulato, Durango.

Form discoidal; compressed; whorls increasing rapidly in height, slowly in width, embracing more than half of preceding whorls. Whorl section elongate-ellipsoidal, thicker in lower third; flanks flattened, inclined toward venter above, evenly convex below. Umbilicus rather small for genus, shallow; umbilical wall low, gently inclined; umbilical shoulder rounded. Venter truncated, narrow, flattened in youth, somewhat convex on older whorls.

To diameter of about 35 mm., ribs rise on umbilical shoulder, regularly bifurcate below or at mid flank, and bend forward across upper third of whorl sides. They cross venter in straight line, forming small clavi on prominent ventro-lateral margins. On last half of outer whorl, sculpture consists of regularly alternating, falciform primary and secondary ribs. Primaries rise on umbilical wall, are directed obliquely forward on lower third of flanks, backward or radial on middle third, and curve forward again on upper third to form indistinct, thickened clavi on ventro-lateral angles. Secondaries rise progressively higher on flanks anteriorly, and last part of outer whorl tends to flare laterally. All ribs equal on venter, where they swing slightly forward. Both primaries and secondaries fade in relief with age, becoming indistinct on outer part of last whorl, where all ribs widen and are gently rounded toward venter, being broader than the interspaces. Septal suture not known.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 20197	61?	31	13	15

REMARKS: *Dufrenoya bösei* Humphrey is characterized and distinguished from *D. justinae* (Hill) by a regular bifurcation of the ribs at a diameter where the latter exhibits quite regular alternation of primaries and secondaries; by the width and decrease in prominence of the ribs, and by the rounding of the venter on the outer whorl. This species is also apparently much more laterally compressed than is *D. justinae* (Hill). Similar diameters of the latter show a much wider venter and whorl section, and none shows the tendency to flare on the outer whorls. This species is named in honor of the late Emil Böse, notable contributor to the paleontology of the Cretaceous formations in Mexico and Texas.

DEPOSITORY: Holotype U. M. 20197 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. One mile, N 2° W, from the house at Rancho El Mulato, Río Nazas, Durango.

Dufrenoya durangensis Humphrey n. sp.

(Plate 9, figures 3, 4)

DESCRIPTION: The following observations are made on an incomplete internal cast and its corresponding and more complete natural mold, from which plastotypes have been prepared for study.

Form discoidal; compressed; whorl section narrowly ellipsoidal, almost rectangular, about three times as high as wide, slightly thicker in lower third, apparently embracing about one half. Umbilicus narrow for the genus; umbilical wall inclined, rounded; umbilical shoulder not well developed. Venter truncated, narrow, slightly convex.

Sculpture consists of regularly alternating, falciform primary and secondary ribs. Primaries rise at whorl suture, curve gently forward across umbilical shoulder, backward on mid flank, slightly forward again to ventro-lateral margins. Secondaries rise toward middle of flanks or on upper third. All ribs flatten and widen considerably toward venter and form well-developed, narrow clavi on ventro-lateral angles. Ribs appear to cross venter transversely only as low swellings between paired clavi. All ribs wider than interspaces on upper third of flanks and appear to become more widely separated on anterior portion of outer whorl. Septal suture not known.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 23972.....	43	19?	6	11.7

REMARKS: This species resembles *Dufrenoya dufrenoyi* (d'Orbigny) but is distinguished from it by the flattening and widening of the ribs toward the venter and by the prominent swellings on the venter between the opposed clavi. *Dufrenoya stenzeli* Humphrey has much finer ribbing and a smooth venter.

DEPOSITORY: Holotype U. M. 23972, corresponding natural mold, and Plastotype U. M. 23973 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. About 1 mile, N 2° W, from the house at Rancho El Mulato, Río Nazas, Durango.

Dufrenoya mulatoensis Humphrey n. sp.

(Plate 9, figures 11, 12)

DESCRIPTION: Two whorl fragments represent this species and form the basis for the following observations.

Shell compressed; discoidal; apparently embracing about one-third of preceding whorls. Whorl section thinly ellipsoidal, flanks gently convex below, flattened above and inclined toward venter. Umbilical wall abrupt; umbilical shoulder strongly rounded. Venter truncate, slightly convex, prominent ventro-lateral angles.

Surface of shell ornamented by numerous (40 to 45 per whorl) primary and secondary ribs. Primaries rise on umbilical wall, about midway between whorl suture and umbilical shoulder; most prominent and bend slightly forward on lower third of flanks, curve backward on middle third and forward again on upper third to form small, scarcely clavate, but pronounced tubercles on ventro-lateral angles. Secondaries begin near mid flank and generally alternate regularly, one being intercalated between two primaries. Occasionally, two primaries may follow. Interspaces about twice as wide as ribs. All ribs prominent and equal on venter and rounded in transverse section. Suture line unknown.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 23968	48?	20	10.7	17
Paratype U. M. 16184	55?	22	?	?

REMARKS: This species approaches *Dufrenoya justinae* (Hill) but differs from it in having finer and much more numerous ribs and in the slight convexity of the venter. Also, the secondaries begin much higher on the flanks in the new form, and all ribs are spaced wider than in *D. justinae* (Hill). From *D. bösei* Humphrey, it differs by its finer costation, by absence of bifurcating ribs, and by its pointed and much smaller ventro-lateral tubercles.

DEPOSITORY: Holotype U. M. 23968 and Paratype U. M. 16184 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Cañón Fernandez, near Rancho El Mulato, Durango and from a canyon near the Williams Ranch in the Santa Rosa Mountains west of Musquiz, Coahuila.

Dufrenoya scotti Humphrey n. sp.

(Plate 9, figures 5, 6)

1940 *Dufrenoya* aff. *dufrenoyi* (d'Orbigny), Burckhardt sp., in SCOTT, Cretaceous Cephalopods, p. 1027 (pars), pl. 62, figs. 3–4, *not* pl. 61, figs. 7–8.
non D. aff. *dufrenoyi* (d'Orb.) BURCKHARDT, 1925, pl. IX, figs. 1–4, 7–9.

DESCRIPTION: A Mexican example in the collections of the Museum of Paleontology, University of Michigan, appears to be identical with the larger of the two forms figured by Scott (1940, pl. 62 only, figs. 3–4) as *Dufrenoya* aff. *dufrenoyi* (D'Orbigny), Burckhardt sp. It is believed that the two specimens represent a new species for which the name *Dufrenoya scotti* is proposed. Scott's specimen is designated as the holotype. The following observations are based on the hypotype (U. M. 23960), which exhibits the characteristic ornamentation and whorl section.

Form compressed; discoidal; sides flattened, inclined toward venter. Whorl section subellipsoidal, more than twice as wide as high, thickest in lower third. Umbilicus moderately wide, shallow; umbilical wall low, acute; umbilical shoulder strongly rounded. Venter truncate, flattened, ventro-lateral angles prominent.

Ornamentation consists of flexuous to almost radial, rather widely spaced and fine primary and secondary ribs which alternate irregularly. Primaries rise high on umbilical wall or at umbilical shoulder, are flexuous across flanks and bend forward above to form small clavi on ventro-lateral angles. One or two intercalated secondaries rise at various levels on flanks and are usually less prominent than the adjoining primaries. Ribs missing or greatly attenuated across venter on early part of whorl but with age are transverse and fairly prominent across venter. Ribs much narrower than interspaces. Septal sutures unknown.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype (Univ. Texas 1170)	65	27.6	18.7	21.5
Hypotype (U. M. 23960)	46?	18.6	11	18?

REMARKS: This species is close to *Dufrenoya* sp. *A* (Pl. 9, figs. 9, 10) but differs from it chiefly by finer and more widely spaced costae, by longer primaries, and by shorter secondaries. The ribbing is much less prominent on the venter and less regularly alternating than in either *D. justinae* (Hill) or *D. mulatoensis* Humphrey (Pl. 9, figs. 11, 12).

DEPOSITORY: Holotype, University of Texas 1170, in the collections of the Bureau of Economic Geology, University of Texas, Austin, Texas. Hypotype U. M. 23906 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Cañón de San Antonio, Sierra de Los Muertos, Coahuila. Holotype from the lower part of the lower "Glen Rose" formation. Taken from a depth of 6202–6206 feet in a core from the Standard Oil Fudicker No. 1 well in Webster Parish, Louisiana (Locality M58 of Scott, 1940, p. 1028).

Dufrenoya sp. *A*

(Plate 9, figures 9, 10)

DESCRIPTION: Several fragments of a *Dufrenoya* from southeastern Coahuila appear to be different from any species recognized by the writer and are here noted.

Form thinly discoidal; sides flattened, subparallel. Whorl section subrectangular, much higher than wide, little embracing. Venter truncate, slightly convex; umbilical wall gently sloping.

Shell ornamented by rather fine, flexuous, irregularly alternating primary and secondary ribs. Primaries rise near whorl suture, are directed obliquely forward across lower flanks, and are convex backward on upper third of whorl side. Two primaries may follow. Secondaries long, rising well down on flanks, and are equal in width and prominence to primaries on upper flanks. All ribs end at prominent ventro-lateral angles in small clavi which are about as long as width of rib interspaces. Venter appears smooth on earlier part of whorls, but with growth much-attenuated ribs cross venter transversely. Suture line not known.

Abnormal sculpture is shown on the smaller of the two specimens for which measurements are given below (U. M. 23973). Between two normal primary ribs, a pair of secondaries is intercalated. These start high on flanks, are almost indistinct, and form pointed tubercles one-third the size of adjoining clavi on each side of venter.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
U. M. 23973	?	22	9.6	?
U. M. 22530	?	31?	15?	?

REMARKS: In the development of the venter, this form approaches *D. codazziana* (Karsten) but differs from it in the irregularity of its ribbing and by its longer secondaries. The specimens referred by Scott (1940, pl. 61, figs. 7–8) and by Burckhardt (1925, pl. X, figs. 1, 4, 7) to *D.* aff. *dufrenoyi* (D'Orbigny) are very similar to *D. codazziana* (Karsten) and should be referred, perhaps, to that species.

DEPOSITORY: U. M. 23973 and 22530 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Cañón de San Antonio, Sierra de Los Placeres, Coahuila, Mexico.

Dufrenoya sp. *B*

(Plate 9, figures 7, 8)

DESCRIPTION: The following description is based on one pyritized whorl segment, considered too fragmentary to merit a trivial name.

Form discoidal; somewhat compressed; increasing rapidly in height, slowly in width. Whorl section elongate oval; flanks flattened above, rounded below, thickest just below mid flank. Umbilicus shallow; umbilical shoulder indistinct; umbilical wall gently inclined. Venter truncate, somewhat excavated; ventro-lateral angles acute.

Sculpture consists of fine, irregularly alternating, falciform primary and secondary ribs. Surface shell marked by fine, wavy striae. Primary ribs rise low on umbilical wall and bend sharply forward from umbilical shoulder. They are radial or slightly curved backward on middle of flanks, are inclined slightly forward above, and terminate on ventro-lateral margins in prominent, rather widely

spaced, narrowly elongate clavi. Primaries most prominent in umbilical region, fading and widening ventrally. Two primaries may follow. Secondaries begin low on flanks, some reaching almost to umbilical shoulder; most prominent below and fade toward venter, forming clavi on ventro-lateral angles equal to those formed by primary ribs. Interspaces wider than ribs. Venter smooth and slightly concave. Suture line very similar to that of *Dufrenoya dufrenoyi* (D'Orbigny). Large, symmetrically trifid, first lateral lobe is about twice as long as short ventral lobe.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Figured specimen U. M. 21757.....	?	16.5	11.4	?

REMARKS: This form exhibits characters midway between those of *D. lurensis* (Kilian) (1888, pl. XX, figs. 2a–b) and *D. stenzeli* Humphrey. The whorl section is much wider than in examples of equal whorl height of either *dufrenoyi* or *stenzeli* but is narrower than in *lurensis*. The clavi are more prominent; there are fewer ribs than in *stenzeli*, and the secondaries seem to be generally longer in the present form. *D. dufrenoyi* (D'Orbigny) has clavi which are much smaller, closer together, and less elongate.

DEPOSITORY: Figured specimen U. M. 21757 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: Upper member, La Peña formation. Cuesta del Cura, Sierra de Parras, Coahuila. Collection I 4 of Ralph W. Imlay, 1936.

Genus *Burckhardtites* Humphrey n. gen.

1925 *Neocomites* BURCKHARDT, Río Nazas, p. 14, pl. III, figs. 4–7.
1940 *Neocomites* SCOTT, Cretaceous Cephalopods, p. 974.

The name *Burckhardtites* is here introduced as a generic term for the form described by Burckhardt (1925, p. 14) as *Neocomites nazasensis* Burckhardt from the upper Aptian of Rio Nazas, Durango, Mexico. As the writer understands the genus *Neocomites*, it is characterized by very involute, much compressed forms with ribs inclined forward and equally spaced and which bifurcate, both from umbilical tubercles and at mid flanks. According to Sayn (1907) the genus disappears in the Hauterivian. Spath (1923b, p. 31) has restricted *Neocomites* to include only the group of *Ammonites neocomiensis* D'Orbigny, as represented by the Drome forms figured by Sayn (1907, pl. VII, figs. 4–11). In any case the example referred by Burckhardt to *Neocomites* is an upper Aptian ammonite, as proved by its occurrence in beds with *Dufrenoya*, *Cheloniceras*, and *Colombiceras*. It is closer to *Dufrenoya* than it is to *Neocomites*, but it is distinguished from the former by its more irregular ribbing, by the double curve of the ribs across the flanks, and by the characteristic sudden increase in height seen in the body whorl of most of the species. Included in the genus are five other species, described as new from various Gargasian (upper Aptian) localities in northern Mexico. The writer believes the six species, here assigned to *Burckhardtites*, represent at least three groups, each of which would perhaps have generic ranking, were more and better-preserved material available for study.

Features common to all the species include a more or less compressed discoidal form, flattened venter with prominent ventro-lateral angles, and characteristic curving of the ribs across the flanks. Ribs convex backward or radial on lower part of flanks, convex forward near mid flanks, and convex backward again on upper third of flanks. Characteristic of most of the species here described is rapid increase in whorl height, which may or may not be acompanied by crowding or change in sculpture on anterior portion of living chamber. Where known, imperfectly preserved sutures seem to be of parahoplitid type. *Burckhardtites nazasensis* (Burckhardt) is designated as the genotype.

Burckhardtites nazasensis (Burckhardt)

(Plate 10, figures 1–5)

1925 *Neocomites nazasensis* BURCKHARDT, Río Nazas, p. 14, pl. III, figs. 4–7.

The following is a literal translation of Burckhardt's original description:

"Shell flattened, not very involute. Somewhat convex flanks pass into a not very high, but abrupt, umbilical wall. Venter truncated, flattened, and narrow. Transverse section much higher than wide, oblong, with its greatest thickness somewhat within the middle of the flanks.

"Surface of the flanks ornamented with narrowed, fine, flexuous costae. The latter consist of principal costae which rise on the umbilical wall and one or two intercalated costae, which appear in the interspaces near the umbilical region, or toward the middle of the flanks. The costae are inflected forward before reaching the middle of the flanks and backward on the upper half of the flanks, being quite falciform on the latter part. The majority of the costae are of equal strength. Only a few of the principals, generally alternatively, thicken slightly on the lower third of the flanks, where they are somewhat prominent and stand out on the umbilical border as tuberculiform prominences.

"All costae thicken toward the ventral margin where they end, forming slight marginal tubercles. The venter is almost entirely smooth, with only weak transverse striae being observed on it."

This species is characterized by the crowding of the primary ribs on the anterior part of the outer whorl. The earlier whorls commonly show a regular alternation of primary and secondary ribs which are slightly narrower than the rib interspaces. On the older whorls the ribs and interspaces are subequal, especially on the upper flanks The ventro-lateral tubercles are slightly clavate and may be directed somewhat inward toward the plane of symmetry. Ribs cross the venter as fine straight lines on the older whorls, but may be considerably attenuated and even interrupted in the younger stages.

Numerous fragments, collected by the writer from the La Peña formation at several localities in the Sierra de los Muertos, agree very closely with Burckhardt's figures and descriptions. Two of these forms are here figured (Pl. 10, figs. 1–3).

Burckhardtites nazasensis (Burckhardt) has been cited by Imlay (1936, p. 1121) from the upper member of the La Peña formation on the Cuesta del Cura in the Sierra de Parras, Coahuila. The Parras specimens, one of which is here figured (Pl. 10, figs. 4, 5), differ slightly from the Nazas type in having a wider and more rounded venter on the older whorls. Also the Parras forms seem to show greater crowding of the ribs and less regular ornamentation. This is due in part to the failure of some of the primary ribs to reach the umbilicus and partly to the relatively lesser prominence of the secondary ribs on the upper part of the flanks.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype	58	27	15.5	18
Hypotype U. M. 22555	?	40?	18	25?
Hypotype U. M. 24255	56?	28?	16	18
Hypotype U. M. 24256	?	32	13.5	?
Hypotype U. M. 21755	70	31.5	16.3	21

DEPOSITORY: Holotype in collections of the Instituto Geologico de Mexico, Mexico, D. F. Hypotypes U. M. 22555, 24255, 24256, and 21755, in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Holotype from near Rancho El Mulato, Rio Nazas, Durango. Hypotypes U. M. 22555, 24255, and 24256 from Rincon de San Gregorio, Sierra de los Muertos, Coahuila. Hypotype U. M. 21755 from upper member of La Peña formation, Cuesta del Cura, Sierra de Parras, Coahuila.

Burckhardtites kellumi Humphrey n. sp.

(Plate 10, figures 7, 9)

DESCRIPTION: The following notes are based on one incomplete internal cast, the inner whorls of which are poorly preserved.

Form discoidal; compressed; flanks convergent, slightly convex above, more rounded below. Whorl section subellipsoidal, much higher than wide, increasing greatly in height anteriorly. Moder-

ately evolute, inner whorls seem to be more embracing than body whorl. Umbilicus moderate size; umbilical wall low, abrupt; umbilical shoulder rounded. Venter truncate, flattened; prominent ventro-lateral angles.

Sculpture consists of quite regularly alternating primary and secondary ribs. Primaries rise high on umbilical wall, are convex backward or radial on lower third, convex forward on middle third, and convex backward once more on upper third of flanks. Secondaries rise from interspaces between adjoining primaries slightly below mid flanks and follow a parallel course toward venter. On posterior half of outer whorl, ribs are rather coarse and widely spaced. Primaries thicken considerably in umbilical region and stand out strongly as transversely elongate swellings on umbilical shoulder. They maintain their strength across the flanks but fade and flatten near venter. All ribs on posterior part of last whorl form prominent clavate tubercles on ventro-lateral margins, being greatly attenuated or interrupted on venter. Ribs subequal in size and narrower than interspaces. On anterior portion of last whorl, all ribs are much finer and equal in size. Umbilical swellings subdued, while ventro-lateral clavi change into bullae which pass as fine straight ridges across ventral area. Septal suture unknown.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 22549	58	25	14	20.5

REMARKS: This species differs from *Burckhardtites nazasensis* (Burckhardt) by its much wider venter, greater regularity of its ribbing, and extreme coarseness of the sculpture in the younger stages. Further, the umbilical swellings in the new form are much more common and prominent than the slight thickening shown in the umbilical region on only a few of the primary ribs in Burckhardt's species. This species is named in honor of Lewis B. Kellum of the University of Michigan.

DEPOSITORY: Holotype U. M. 22549 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Rincón de San Gregorio, Sierra de los Muertos, Coahuila.

Burckhardtites gregoriensis Humphrey n. sp.

(Plate 11, figures 3, 4)

DESCRIPTION: One whorl fragment, undoubtedly belonging to *Burckhardtites*, has a distinctive ornamentation and merits description.

Form discoidal; compressed; apparently little embracing. Whorl section subellipsoidal, higher than wide, thickest in lower third, flanks evenly convex. Umbilicus appears to be wide; umbilical wall abrupt, oblique; umbilical shoulder strongly rounded. Venter truncate, narrow, slightly convex. Marked ventro-lateral angles.

Ornamentation consists of numerous, fine, irregularly alternating, primary and secondary ribs. Primaries faint on umbilical wall, directed posteriorly over umbilical shoulder, curve convex forward before arriving at mid flanks, are convex backward on upper half of flanks. Two primaries may follow, or every other primary may be indistinct in umblical region, in which case adjoining stronger primaries thicken, forming slight swellings on upper umbilical wall and shoulder. One or two shorter ribs intercalate between primaries. When single, the secondary rises just below mid flank. When two are present, the more anterior begins well down on flanks near umbilical shoulder, the posterior being considerably shorter. All ribs fade and widen ventrally and are equally spaced and somewhat flattened over venter which they cross transversely without forming ventro-lateral tubercles. Suture line not known.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 24257	68?	26	16.3	25.5?

REMARKS: *Burckhardtites gregoriensis* Humphrey is easily distinguished by the fineness of its costation and by the absence of ventro-lateral tubercles.

DEPOSITORY: Holotype U. M. 24257 in the University of Michigan, Museum of Paleonotology.

OCCURRENCE: La Peña formation. Holotype from Rincón de San Gregorio, Sierra de los Muertos, Coahuila. Another example of this species comes from the upper member of La Peña formation, Cuesta del Cura, Sierra de Parras, Coahuila (coll. 41 of Ralph W. Imlay).

Burckhardtites sp. *A*

(Plate 11, figures 2, 8)

DESCRIPTION: An example of *Burckhardtites*, distinct from but closely related to, *B. nazasensis* (Burckhardt) is represented in our collections by one large whorl segment. This form is here described to illustrate possible specific variations in this genus.

Form discoidal; compressed; flanks flattened convex. Whorl section subellipsoidal, higher than wide, increasing slowly in height and width. Umbilicus apparently wide; umbilical wall high, almost perpendicular; umbilical shoulder strongly rounded. Venter truncated, slighdy convex, wide, about half whorl width.

Sculpture consists of rather robust, irregularly alternating, quite widely spaced primary and secondary ribs. Primaries rise well down on umbilical wall, are radial or slightly directed backward on umbilical shoulder, convex forward at or below mid flanks, convex backward on upper third of flanks. Two primaries may follow. One or two secondaries may rise in interspaces just below middle of flanks and are slightly less prominent than primaries on whorl sides. Occasionally one primary may be quite weak in umbilical region, giving appearance of three intercalated secondaries. All ribs thicken somewhat as they curve forward to ventro-lateral margins, but tubercles are not formed. Ribs cross venter transversely, being somewhat attenuated and flattened. Interspaces generally much wider than ribs. Suture lines unknown.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Figured specimen U. M. 16584	?	29	18	?

REMARKS: This form may easily be distinguished from *B. nazasensis* (Burckhardt) by its coarser and more widely separated ribs. Also the umbilicus in the present form is apparently much larger.

DEPOSITORY: Figured specimen U. M. 16584 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: Upper member of La Peña formation, Cuesta del Cura, Sierra de Parras, Coahuila (coll. 41 of Ralph W. Imlay, 1936).

Burckhardtites sp. *B*

(Plate 10, figures 6, 8)

DESCRIPTION: Further variation from Burckhardt's species is shown by two whorl fragments collected by Imlay (1936, Locality 41) in the Sierra de Parras, Coahuila.

Both specimens are inflated, apparently little embracing, the whorl sections being almost as wide as high, the greatest thickness being just below mid flanks. Each seems to increase slowly in height and width and to be rather widely umbilicate. Umbilical walls inclined, shoulders evenly rounded.

The smaller example (Pl. 10, figs. 6, 8) shows regular alternation of strong, flexuous primary and secondary ribs which are equal in strength across flanks but which flatten and widen ventrally. Primaries rise near umbilical suture, increasing in prominence on upper part of umbilical wall and shoulder. Secondaries exceptionally long, beginning in interspaces near umbilical border. All ribs form obscure bullate prominences on strong ventro-lateral angles, being transverse and somewhat attenuated across venter.

The larger specimen (U. M. 24258) has still more inflated whorl section, and the secondary ribs

are generally shorter and more irregularly alternating. Also the uppermost part of flanks is more inclined toward venter, giving ovoidal outline to whorl section, in contrast to subtrapesoidal appearance of smaller form.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Figured specimen U. M. 24005	?	30	23	?
U. M. 24258	?	34	29	?

DEPOSITORY: Figured specimen U. M. 24005 and U. M. 24258 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: Upper member of La Peña formation. Locality 41 of Imlay (1936), Cuesta del Cura, Sierra de Parras, Coahuila.

Burckhardtites sp. *C*

(Plate 11, figures 5–7)

DESCRIPTION: One septate whorl fragment in our collections appears to belong to *Burkhardtites* and forms the basis for the following observations.

Form discoidal; compressed; flanks convex below, inclined toward venter above. Whorl section subellipsoidal, higher than wide, increasing rather evenly in height and width. Umbilical wall low, inclined; umbilical shoulder evenly rounded. Venter truncated, narrow, flattened.

Numerous fine, somewhat irregularly alternating primary and secondary ribs adorn shell. Primaries begin high on umbilical wall and are radial or directed slightly posteriorly across umbilical shoulder; convex forward below middle of flanks and curve backward above before bending forward again to terminate at ventro-lateral margins. One or two secondaries rise about midway between umbilical shoulder and mid flanks, the more anterior being slightly longer when two are intercalated. All ribs are equal and slightly falciform on upper third of flanks, terminating on ventro-lateral angles in small tubercles, which are directed inward toward plane of symmetry and a little forward. That part of venter preserved is smooth between tubercles. Ribs slightly narrower than interspaces. Septal suture was probably more frilled than is shown in drawing (Pl. 11, fig. 5). First lateral lobe slightly deeper than siphonal lobe. First lateral saddle wider than first lateral lobe and divided by small, asymmetrically bifid lobe.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Figured specimen U. M. 22671	?	15.5	11.5	?

REMARKS: This species has a much narrower venter, finer costation, and the ventro-lateral tubercles are more prominent than in *Burckhardtites nazasensis* (Burckhardt). The costation in the present form is not so fine as that shown by *Burckhardtites gregoriensis* Humphrey.

DEPOSITORY: Figured specimen U. M. 22671 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Rincón de los Potreritos, Sierra de los Muertos, Coahuila.

Burckhardtites imlayi Humphrey n. sp.

(Plate 11, figures 10, 11)

DESCRIPTION: The following remarks are based on the holotype, an incomplete and rather distorted specimen which imperfectly shows the inner whorls.

Form thickly discoid; flanks gently convex; whorls apparently little embracing. Whorls in-

crease gradually in height and width, expanding suddenly in flared aperture. Whorl section subovoidal in outline, height and width subequal or a little higher than wide. Umbilicus moderately wide; umbilical wall low, abrupt; umbilical shoulder evenly rounded. Venter truncated, flattened, rather broad.

Ornamentation on posterior part of fragmentary outer whorl consists of relatively few, coarse, regularly alternating primary and secondary ribs. Primaries rise on upper umbilical wall and shoulder, are convex forward below mid flanks and convex backward on upper half of whorl sides. Secondaries begin in interspaces near middle of flanks and are equal to primaries on ventral third of flanks. On younger whorls, all ribs terminate at ventro-lateral angles in weak, clavate prominences. Anteriorly, ribs appear to cross venter transversely but are much attenuated. Toward aperture, shell flares laterally, accompanied by considerable increase in whorl height Last 10 ribs before apertural margin extremely fine, crowded, regularly alternating primaries and secondaries. Latter extend much lower on flanks than do secondary ribs on posterior portion of outer whorl. Near aperture, venter widens considerably, ventro-lateral angles become rounded, and no tubercles are present. Fine ribs lose relief, but cross venter transversely. Septal suture not known.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 22441 (at aperture).....	88?	35.5	23.5	30
Holotype U. M. 22441 (at diameter of).....	60	23	19.5	24
Holotype U. M. 22441 (at diameter of).....	44	16	16	15?

REMARKS: This form, together with *B. palumbes* Humphrey and *B. ehlersi* Humphrey, differs from all other species here referred to *Burckhardtites* by its more depressed whorl section and by the apertural flaring. *B. imlayi* Humphrey differs from *B. palumbes* Humphrey by its much coarser ribbing and wider venter. This species is named in honor of Ralph W. Imlay.

DEPOSITORY: Holotype U. M. 22441 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Puerto Las Palomas, Sierra de los Muertos, Coahuila.

Burckhardtites palumbes Humphrey n. sp.

(Plate 11, figures 1, 9; Plate 12, figures 1–3)

DESCRIPTION: This species is represented by two almost entire, but rather distorted specimens which show the body chamber. The suture is poorly shown, and the innermost whorls are imperfectly preserved.

Form discoidal; compressed; embracing about one-half; flanks evenly convex. Whorl section subellipsoidal, higher than wide. Umbilicus moderate size; umbilical wall low, abrupt; umbilical shoulder strongly rounded. Venter truncate, flattened, prominent ventro-lateral angles. Whorl flares on anterior part of body chamber, increasing rapidly in height and width toward aperture.

Shell marked posteriorly by rather regularly alternating, numerous primary and secondary ribs. Primaries start low on umbilical wall, are finer below and widen on upper half of flanks where they are markedly falciform. Intercalated secondary ribs, (one or two) generally begin on upper half of whorl sides where they are equal in strength to primaries. Where two shorter ribs intercalate, more anterior is usually longer. Rarely, primary rib does not reach umbilicus, giving appearance of three intercalated secondaries. In earlier stages, all ribs terminate at ventro-lateral margins in radially elongate tubercles. With development of shell, tubercles change into narrow clavi, which in turn disappear toward aperture. Anterior end of living chamber ornamented by numerous, fine, crowded, irregularly alternating ribs which pass transversely across widened venter. Septal suture best shown on paratype U. M. 22675 (Pl. 12, fig. 3). Siphonal lobe appears to have sharp median saddle and is longer and narrower than first lateral lobe. Latter is rather wide and asymmetrical. First lateral saddle, broad and undivided, carries several shallow adventitious lobes.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype 22686 (anterior end)	77?	22.4	14?	12.7?
Holotype 22686 (90° from aperture)	41?	17.7	12.3	13.7?
Paratype U. M. 22675 (anterior end)	80?	39?	14.2	22.3
Paratype U. M. 22675 (90° from aperture)	43.6	19	12.3	13.5

REMARKS: This species is more involute and has finer costation and a narrower venter than *B. imlayi* Humphrey. Also the whorl section away from the aperture is less depressed in the present form.

DEPOSITORY: Holotype U. M. 22686 and Paratype U. M. 22675 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Rincón de los Potreritos and Puerto Las Palomas, Sierra de los Muertos, Coahuila.

Burckhardtites ehlersi Humphrey n. sp.

(Plate 12, figures 4–6)

DESCRIPTION: This species is represented by one specimen, the holotype, whose anterior end appears to show the body chamber, probably not far from the aperture. The inner whorls are not shown.

Shell discoidal; small; robust; moderately evolute, embracing about one-half. Whorl section of subequal height and width, thickest in lower third; greatly expanding anteriorly. Anterior end of shell much higher than wide, flanks convex below, flattened and inclined above toward broadly truncated venter. Umbilicus moderately wide, deep; umbilical wall almost straight; umbilical shoulder strongly rounded.

Sculpture on outer whorl changes in marked manner anteriorly. Posterior portion bears regularly alternating, coarse, widely spaced primary and secondary ribs. Long ribs begin on umbilical wall and are radial, considerably swollen, and prominent across umbilical shoulder. They curve forward on lower flanks, bend backward, and are flattened and falciform on upper flanks, curving forward again to terminate in prominent clavate tubercles on ventro-lateral angles. Shorter, intercalated ribs are always single, rise well down on lower flanks, and are equal in strength to primaries above. Venter smooth or marked slightly by faint swellings between opposed clavi. Last six ribs on extreme anterior part of outer whorl are crowded, narrowed, and cross venter transversely, first much attenuated and then as fine, prominent ridges. Tubercles become less clavate and tend to disappear anteriorly, although still present on last ribs shown. Ribs generally narrower than interspaces. Suture line not known.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 22539 (anterior end)	54	25	15.3	18
Holotype U. M. 22539 (90° from anterior end)	31.8	12.2	13	12

REMARKS: This species differs from *B. imlayi* Humphrey and *B. palumbes* Humphrey in having the change in whorl section and ornamentation take place at a much smaller diameter than in either of those species. It is further distinguished by the thickening of the primary ribs over the umbilical shoulder and by the greater length of its secondaries. The whorl section also seems to be relatively most depressed on the posterior part of the outer whorl. This species is named in honor of George M. Ehlers of the University of Michigan, whose advice on nomenclatural problems during the present investigation has been greatly appreciated.

DEPOSITORY: Holotype U. M. 22539 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Cañón de San Antonio, Sierra de los Muertos, Coahuila.

Genus *Parahoplites* Anthula 1900 emend. Spath 1930

Genotype: *Parahoplites melchioris* ANTHULA, Kreidefossilien, p. 112, pl. VIII (VII), figs. 4–5, 1900 (1899).

Parahoplites in its original sense, as interpreted first by Anthula and later by Jacob (1907a, p. 47) and by Kilian and Reboul (1915, p. 36), included a considerable variety of forms now referred to at least six other genera, numbering such distinct members as *Deshayesites*, *Leymeriella*, and *Protohoplites*. In the strict sense of present usage, *Parahoplites* is confined to species similar to those of the groups of *melchioris-nutfieldensis* and *campichei*. As such, it consists of discoidal, little-compressed forms with subrounded to subovoidal whorl sections, ornamented by usually flexuous and prominent ribs which may or may not bifurcate. The ventral area is arched, and the ribs cross it transversely or slightly curved and are somewhat strengthened thereon.

In a discussion of the genus, Scott (1940, p. 1029) mentioned that the genotype was "characteristic of the lower Gault" (Middle Albian) and that "most of the species indicate an early or middle Albian age." The writer disagrees. Far from being characteristic of the "lower Gault", *Parahoplites melchioris* Anthula very likely comes from the *subnodosocostatum* zone of the Gargasian, as has been suggested by Spath (1921b, p. 32). In regard to Scott's second statement, no ammonite species from the English Gault is assigned to the family Parahoplitidae by Spath in his monograph on the Gault Ammonoidea (1923b–1943). It may be said that *Parahoplites* (s. s.) is common in both the upper Aptian and the lower Albian (*nodosocostatum-tardefurcatus* zones) but that by itself the genus is not especially diagnostic for either substage.

Parahoplites mexicanus Humphrey n. sp.

(Plate 12, figures 7, 8)

DESCRIPTION: This species is represented by one specimen.

Form compressed; thin; discoidal; moderately evolute, flanks flattened, whorls embracing about one-third of preceding whorls. Umbilicus medium size, shallow; umbilical wall inclined, oblique; umbilical shoulder gently rounded. Venter slightly flattened in youth, narrowly arched on anterior part of outer whorl.

Posterior part of last whorl marked by numerous, fine, irregularly alternating, simple primary and secondary ribs. Primaries rise on umbilical wall and are flexuous and inclined forward across flanks. Two or three primaries may follow. Secondaries start just above umbilical shoulder and are equal to primaries on upper flanks and venter, which all ribs cross unaltered, either transversely or bending weakly forward. On anterior part of outer whorl, ribs are coarser and more widely spaced. Primaries prominent on lower third of flanks, decreasing in strength toward venter where all ribs are equal. Alternation of ribs more regular, one secondary intercalating between primaries and beginning at about mid flank. Ribs of this species have unique cross section, especially on venter. Posterior edge of ribs high and abrupt and may be somewhat excavated behind. Anterior side of ribs concave in section, sloping forward to posterior edge of next following rib. Suture unknown.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 22668	39	17.5	8.5	13.5

REMARKS: This species is characterized by the change in ornamentation which takes place on the outer whorl, by the flattened flanks, and by the narrow whorl section. It is further distinguished by the peculiar rib section as shown on the venter of the anterior part of the outer whorl.

DEPOSITORY: Holotype U. M. 22668 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Rincón de los Potreritos, Sierra de los Muertos, Coahuila.

Parahoplites cf. *P. multicostatus* Sinzow

(Plate 12, figures 9, 10)

DESCRIPTION: Three small specimens represent this species.

Shell discoidal; robust; increasing rather rapidly in height and width, whorls embracing about half of preceding whorls. Transverse section subovoidal, higher than wide, flanks convex, venter evenly rounded. Umbilicus somewhat small; umbilical wall inclined, oblique; umbilical shoulder rounded.

Surface of shell marked by radial or faintly flexuous, regularly alternating, primary and secondary ribs. Primaries rise on umbilical wall, enlarging gradually over upper flanks and venter. One secondary rib regularly intercalates between two primaries, beginning below middle of flanks and equal in strength to primaries on upper third of whorls. All ribs cross venter without alteration, are equally spaced, and bend weakly forward. Width of ribs slightly less than interspaces. Suture line not known.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Figured specimen U. M. 24259	26.5	12	10.5	9
U. M. 22676	23	10.2	8.2	8.5

REMARKS: The Mexican examples in our collections agree very well in ornamentation, whorl shape, and coiling with *Parahoplites multicostatus* Sinzow (1907, p. 459, pl. II, figs. 5–11) from the upper Aptian (*subnodosocostatum* zone) of Mangyschlaks, Russia. Sinzow stated that some of the ribs in his species bifurcated at the umbilical border, although this is not very evident in his illustrations. The innermost whorls are not shown on the present examples, but no bifurcation of ribs is seen on the outer whorls. Therefore, conspecificity cannot be demonstrated between the Mangyschlaks and Mexican forms.

DEPOSITORY: Figured specimen U. M. 24259; another specimen U. M. 22676 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Rincón de los Potreritos, Sierra de los Muertos, Coahuila.

Genus *Acanthoplites* Sinzow 1908 emend Kilian 1913 emend Spath 1923

GENOTYPE: ***Parahoplites aschiltaensis*** ANTHULA, Kreidefossilien, p. 117, pl. X (IX), figs. 2–4, 1900.

Sinzow proposed *Acanthoplites* to include the forms previously referred by Anthula to his "group of *Parahoplites aschiltaensis*". In 1913, Kilian (p. 349) considered *Acanthoplites* (s. l.) as embracing six groups of species, most of which are now assigned to other genera. Spath (1923b, p. 64) restricted *Acanthoplites* to the "group of *'Parahoplites' aschiltaensis* Anthula and *'Douvilleiceras' bigoureti*, Seunes", and at the same time proposed *Colombiceras* and *Hypacanthoplites* for forms which Kilian would have included in his group of *Acanthoplites crassicostatus* (D'Orbigny).

In its present restricted sense, *Acanthoplites* includes discoidal, little-compressed, moderately evolute forms with tuberculate, somewhat *Cheloniceras*-like inner whorls and adult stages like *Parahoplites* (s. s.).

Another of Kilian's groups, that of *Acanthoplites gargasiensis* (D'Orbigny), appears to be distinct from the groups of *aschiltaensis* and *bigoureti* and probably deserves a separate generic name. Species of this group are little embracing, with subquadrangular to subovoidal whorl sections and are especially characterized by having numerous, short, intercalated secondary ribs and by the relative prominence of the primaries on the lower flanks. Similar forms are especially abundant in the La Peña fauna and show considerable variation. The two species described below as *Acanthopolites*? are referred to this group. None of the Mexican examples show an attenuation or interruption of the ribs over the venter, as seen in *Ammonites gargasiensis* (D'Orbigny) (1840–1841, p. 199, pl. 59, 5–7) (*see also* Roch, 1926, pl. XVIII), but according to Kilian this character is not especially constant.

Mention should be made here of *Rhytidoplites* Scott (1940, p. 1034), "... said to include those parahoplitids characterized by costae occurring in bundles." Neither of the species referred herein to *Acanthoplites*? fall into Scott's genus, nor do any other forms of the *gargasiensis* group. *R. robertsi*

Scott is much more involute than the present forms and has a rectangular and much higher whorl section.

Acanthoplites potreritensis Humphrey n. sp.

(Plate 12, figures 11, 12)

DESCRIPTION: This species is represented by one incomplete example, which shows characteristic ornamentation and whorl section.

Form discoidal; robust; fairly evolute, whorls embracing about one-fifth of preceding whorls. Whorl section octagonal in youth, nearly as wide as high, increasing more rapidly in height than in width, becoming subovoidal on older whorls. Umbilicus wide, moderately deep; umbilical wall steep and high in youth, more inclined with age; umbilical shoulder sharply rounded in young whorls, gently convex on anterior part of shell. Venter truncated, somewhat excavated in early stages, becoming squarish and broadly convex with growth.

Shell marked by irregularly alternating primary and secondary ribs. Primaries begin well down on umbilical wall, flare out strongly with considerable relief on lower two thirds of flanks and decrease rapidly in prominence, either bifurcating or simple from an elongate node on upper third of flanks. On posterior part of outer whorl, primaries regularly bifurcate from upper flank node but are more widely separated and remain simple on older part of whorl. On inner whorls, all ribs appear to rise on umbilical border, and no secondaries can be observed, although there appears to be an alternation of two weak long costae with more prominent and single, node-forming ribs. On outer whorl, however, one or two secondary ribs may be present between bifurcating primaries. These rise at various levels on flanks but seem to be restricted to upper third and are more regularly alternating on anterior end of last whorl. All ribs slightly attenuated and excavated along midline of venter which they cross transversely. Simple primaries and posterior branch of bifurcating primaries generally more prominent than other ribs on venter. Primaries may be flexed forward weakly or are radial on the lower flanks. Septal suture unknown.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 22652	38	14?	10?	15
Holotype U. M. 22652 (posterior part of outer whorl)	?	9	9	?

REMARKS: This species is characterized by the prominent flaring of the primary ribs on the lower flanks and by the truncated and somewhat concave venter, especially on the early part of the last whorl. The venter in youth thus approaches that of species of *Cheloniceras*, although the whorl section is not depressed. Similarity between height and width of the early part of the last whorl in this species is due largely to the high lateral relief of the primaries. In ornamentation, the present form is close to *Acanthoplites acutecosta* Riedel (1937, p. 43, pl. VIII, figs. 1–6) although in that species there is a slight forward curving of the ribs across an unflattened venter, and there seems to be a regular alternation of simple ribs at a stage when *Acanthoplites potreritensis* Humphrey shows a clear bifurcation of the primaries. The present form resembles *Acanthoplites aschiltaensis* (Anthula) var. *aplanata* Sinzow (1907, p. 481, pl. V, figs. 6–7 only), but the Mangyschlak example does not show the excavation of the venter, and the flaring of the primaries is not so prominent.

DEPOSITORY: Holotype U. M. 22652 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Rincón de los Potreritos, Sierra del Caporal, Coahuila.

Acanthoplites? adkinsi Humphrey n. sp.

(Plate 13, figures 2, 3)

?1925 *Parahoplites* sp. ind. BURCKHARDT, Río Nazas, p. 23, pl. IV, figs. 19–23 only.

DESCRIPTION: One fairly complete specimen, which shows the inner whorls, forms the basis for the following observations.

Shell discoidal; moderately evolute, embracing only about one-fourth of the preceding whorls. Whorl section subovoidal higher than wide, increasing uniformly and gradually in height and width. Umbilicus wide, shallow; umbilical wall low, abrupt on young stages, more gently inclined on outer whorl; umbilical shoulder rounded. Venter evenly arched.

To a diameter of about 14 mm., inner whorls marked by numerous fine ribs, inclined forward, all of which appear to start well down on umbilical wall. Every third or fourth rib is stronger and more prominent than the others, but without seeming to form tubercles. Rarely, appears to be bifurcation of ribs on umbilical shoulder. A change in ornamentation takes place on outer two whorls. Stronger ribs of earlier whorls become more prominent on lower two-thirds of flanks, and finer ribs become fewer in number and begin higher up on whorl sides. This results in fairly regular alternation of primary and secondary ribs. Primaries begin about half way up umbilical wall, gain in strength and are slightly directed backward across umbilical shoulder. They curve weakly forward across flanks, then bend slightly backward across venter, decreasing rapidly in relief and prominence on the upper third of flanks. Secondaries (2 or 1) begin progressively higher on whorl side, until on last half of outer whorl they occupy only upper third of flanks. Last three primaries on outer whorl appear to divide on ventro-lateral margin at point of whorl overlap, but on rest of whorl the ventral sculpture is poorly shown, and bifurcation of ribs cannot be demonstrated. All ribs equal and evenly spaced on venter. Septal suture not known.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 22681	56	21	15	25

REMARKS: In coiling and whorl shape, the new form resembles *Acanthoplites interiectus* Riedel (1937, p. 41, pl. VIII, figs. 8–10) but differs from it in the change in ornamentation and in having more numerous secondaries. In sculpture, this species seems to be closely related to *Acanthoplites acutecosta* Riedel (1937, p. 42, pl. VIII, figs. 1–4 only), but the primaries in that form bifurcate in the young stages, are more prominent on the lower flanks, and the whorls seem more embracing. The two examples described and illustrated by Burckhardt as *Parahoplites* sp. ind. from near El Mulato Ranch, Durango, are probably identical with the new species. The thinner whorl sections shown by his specimens are likely due to deformation. *Acanthoplites gargasiensis* (D'Orbigny) var. *recticostata* (Kilian) as figured by Roch (1926, pl. XVIII, figs. 6–6a) has a similar ornamentation, but the costation is quite radial, and the venter has the excavated appearance of D'Orbigny's species and a subquadrangular whorl section. This species is named in honor of W. S. Adkins of Austin, Texas, important contributer to the Mesozoic stratigraphy and paleontology of Texas and northern Mexico.

DEPOSITORY: Holotype U. M. 22681 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Rincón de los Potreritos, Sierra de los Muertos, Coahuila.

Acanthoplites? sandidgei Humphrey n. sp.

(Plate 13, figures 1, 4)

DESCRIPTION: This species is represented by one specimen, a natural cast, on which the inner whorls are not shown.

Form compressed; discoidal; whorls increasing evenly in height and width, embracing about one-fourth of preceding whorls. Whorl section apparently subovoidal, higher than wide, thickest in lower third. Umbilicus rather wide; umbilical wall low, abrupt; umbilical shoulder rounded. Venter evenly rounded, flanks convex.

Shell marked by rather regularly alternating, primary and secondary ribs. Primaries start on umbilical wall, are strong and convex forward on lower flanks, bending weakly backward across upper flanks. On venter, they are less prominent and essentially transverse. Most primaries are continuous from umbilical border to umbilical border. Occasionally, primary rib starting from umbilical wall on one side will terminate as secondary rib on upper third of other side of shell. When such is the case, the rib immediatly anterior will be of primary length on same side of shell and of secondary

length on side where preceding rib is a primary. One or rarely two secondary ribs intercalate between adjoining continuous primaries. When only one secondary is present, it rises above mid flank. When two intercalate, the more anterior is usually the longer and may extend to lower third of flanks. Secondary ribs tend to be inclined more steeply than primaries which precede them, causing unequal spacing on venter where ribs are subequal in size. Septal suture unknown.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 24297	54	17.5	11?	23.5

REMARKS: This species is characterized by the prominence of the primaries on the lower flanks, by the somewhat greater forward inclination of the secondaries, and especially by the discontinuity of some of the primary ribs on both sides of the shell. The secondaries terminate closer to the adjoining primaries on the posterior part of the whorl, suggesting that the ribs may bifurcate high on the flanks in the younger stages. *Acanthoplites? sandidgei* Humphrey is close to *Acanthoplites acutecosta* Riedel (1937, pl. VIII, figs. 1–4) in whorl shape, coiling, and in the greater inclination of the secondaries. The Colombian species has much more prominent and flaring primaries, the latter being more prominent on the venter than the secondaries and the costation is generally less flexuous than in the present form. This new species is named in honor of John R. Sandidge of San Antonio, Texas.

DEPOSITORY: Holotype U. M. 24297 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Rincón de los Potreritos, Sierra de los Muertos, Coahuila.

Genus *Hypacanthoplites* Spath 1923

GENOTYPE: *Acanthoceras milletianum* (D'Orbigny) var. *plesiotypica* FRITEL, Variations d'*Acanthoceras milletianum* (D'Orbigny), p. 245, text figure 2, 1906.

This genus was proposed by Spath (1923b, p. 64) for the "group of '*Acanthoplites*' *milletianus*, D'Orbigny" of the literature. Species referable to *Hypacanthoplites* range from the upper Aptian to the lower Gault? and are not, as inferred by Scott (1940, p. 1038), restricted to the lower and middle Albian. However, the genotype species appears to be especially characteristic of part of the *tardefurcatus* zone of the lower Albian.

Hypacanthoplites has been interpreted as including rather compressed parahoplitids with radial, rather regularly alternating ribs and flattened flanks and venters. The genotype, however, and closely related varieties described by Fritel (1906, p. 245–247) are little-compressed forms which characteristically exhibit a row of bullate umbilical tubercles and which occasionally bear nodes on the upper flanks. Further, the ribs are usually attenuated across the more or less truncated and flattened venters.

Hypacanthoplites leanzae Humphrey n. sp.

(Plate 13, figures 7–9)

DESCRIPTION: This species is represented by one somewhat distorted specimen, composed of half an adult whorl, which shows the coiling and ornamentation.

Shell discoidal; robust; whorls higher than wide; apparently embracing about half of preceding whorls. Whorl section subovoidal, flanks and venter flattened convex. Umbilicus moderate size; umbilical wall rather high, almost perpendicular; umbilical shoulder strongly rounded.

Sculpture consists of irregularly alternating primary and secondary ribs. On flanks, three, four, or five secondary ribs may be intercalated between the stronger primaries. Primaries rise on umbilical wall, form strong bullae on umbilical shoulders, and are swollen on lower flanks. They cross whorl sides radially or are slightly flexuous, tending to form second row of tubercles at about mid flanks. On upper third of flanks, primaries become less prominent and are transverse or only weakly curved forward across venter, where all ribs are subequal in size. Secondaries slightly more inclined forward

than primaries which precede them, and the most anterior of them is usually the longest, extending almost to umbilical border where it rises close to umbilical bulla of the following primary. Most posterior intercalated secondary ribs rise at or just above mid flanks, very close to subnodular swelling on preceding primary from which it may appear to branch. Such bifurcation of primaries is more apparent than real. All ribs equally spaced on venter and somewhat more narrow than interspaces.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 22637	60	28	23	22

REMARKS: *Hypacanthoplites leanzae* n. sp. is characterized by the prominent umbilical bullae and the numerous secondary ribs. It somewhat resembles the smaller of the two forms figured by Fritel (1906, p. 246, fig. 2) as *Acanthoceras milletianum* (D'Orbigny) var. *plesiotypica* Fritel in coiling and ornamentation. That species, however, has a sharply flattened venter, fewer secondaries, and less prominent umbilical bullae. The new species is not unlike *Acanthoplites milletianum* (D'Orbigny) var. *sinzowi* Roch (1926, p. 290, pl. XVIII, figs. 2a-b only), but the French form does not show the large bullae and appears to be more evolute. *Parahoplites milletianus* (D'Orbigny) as figured by Pervinquiere (1907, pl. VII, figs. 34–35) has a similar arrangement of the secondary ribs, but the costation is generally finer on the Tunisian form, and the umbilical tubercles are weakly developed. The examples described and figured by Burckhardt (1925, p. 21, pl. III only, figs. 14–19) as *Parahoplites* cfr. *milletianus* (D'Orbigny) are not conspecific with the present species. Rather, they seem to be closer to the genotype, although not possessing a flattened venter. This species is named in honor of Armando F. Leanza of Buenos Aires, Argentina.

DEPOSITORY: Holotype U. M. 22637 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Rincón de las Vallas, near Hacienda Saucillo de Arriba, Coahuila.

Hypacanthoplites? rursiradiatus Humphrey n. sp.

(Plate 14, figures 11, 12)

DESCRIPTION: The following observations are based on one fairly well preserved, completely septate example, the holotype (U. M. 22677), on which the innermost whorls are imperfectly shown.

Form discoidal; whorl section subovoidal, little higher than wide, embracing about a quarter of preceding whorl, flanks somewhat flattened. Venter flattened on early whorls, flattened-convex on anterior part of last whorl. Umbilicus quite wide, shallow; umbilical wall low, steep; umbilical shoulder strongly rounded.

Shell marked by equally spaced, more or less regularly alternating, primary and secondary ribs. Rarely, two primaries or two secondaries may follow. Marked backward curving of ribs on upper half of flanks and across ventral area is characteristic. Primaries rise on umbilical wall, thicken rapidly on umbilical shoulder, and maintain their strength across flanks. Secondaries rise from interspaces at, or occasionally slightly above, mid flanks and are equal to primaries on ventro-lateral border where all ribs thicken in transversely elongate swellings. Across mid line of venter, ribs are straight, equally spaced, but thinned and salient. Septal suture unknown.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 22677	58.6	21	19.4	26.8

REMARKS: Because of the somewhat flattened venter and the transverse swellings of the ribs on the ventro-lateral margins, this form is referred with question to *Hypacanthoplites*, even though it is much more widely umbilicate than most of the species referred to that genus and its whorl section is more ovoidal. Also the umbilical tubercles of the genotype (*Acanthoceras milletianum* (D'Orbigny)

var. *plesiotypica* Fritel) mentioned by Fritel (1906, p. 246, fig. 2) are lacking. In degree of evolution, the present species approaches *Acanthoplites interiectus* Riedel (1937, p. 41, pl. 8, fig. 10 only), but that form has a rounded venter with no ventro-lateral thickenings. The inner whorls of the present species show neither tuberculation nor bifurcation of the ribs, characters of *Acanthoplites* s.s., although in whorl shape and width of umbilicus the new species is not unlike the early whorls of the large specimen figured by Anthula (1900 (1899), pl. XI (X), fig. 1) as *Parahoplites aschiltaensis* Anthula, the genotype species of *Acanthohoplites* Sinzow. Species of *Parahoplites* s.s. are characterized by a strengthening of the ribs across a strongly rounded venter, and most of them are more narrowly umbilicate, having relatively higher whorl sections than the present form.

DEPOSITORY: Holotype U. M. 22677 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Rincón de los Potreritos, Sierra de los Muertos, Coahuila.

Family CHELONICERATIDAE Spath, 1923

Genus *Cheloniceras* Hyatt, 1903

GENOTYPE: *Ammonites royerianum* D'ORBIGNY, Pal. Fr. Terr. Cret., p. 365, pl. 112, figs. 3–5, 1841.

In 1925, Burckhardt (p. 25–27) summarized the views of such previous workers as Kilian, Jacob, and Sinzow regarding the genus *Douvilleiceras* de Grossouvre and enumerated most of the described species according to the various groups and subgroups then distinguished by those authors. Burckhardt's Group I, that of *Douvilleiceras albrechti-austriae* (Hohenegger), is now referred to *Procheloniceras* Spath (Genotype *Ammonites stobieszkii* D'Orbigny). His Group II, composed of the subgroup of *Douvilleiceras cornueiianum* (D'Orbigny) and *Douvilleiceras martinii* (D'Orbigny), is now generally assigned to *Cheloniceras* Hyatt. In Group III, Burckhardt included *Douvilleiceras ricordeanum* (D'Orbigny) and *Douvilleiceras royerianum* (D'Orbigny). The first is referred by the present writer to the new genus *Megatyloceras* and the second is the genotype of *Cheloniceras*. Group IV of Burckhardt is now largely included in the genus *Diadochoceras* Hyatt (Genotype *Ammonites nodosocostatum* D'Orbigny), but the latter probably does not admit *Cheloniceras santafecinum* (Burckhardt) (= *Douvilleiceras stoliczkanum* (Gabb) in R. Douvillé, 1906, pl. I, figs. 2–2a = *Cheloniceras boulei* Bassé, 1928, p. 139, pl. VIII, fig. 4). Burckhardt's Group V is *Douvilleiceras* of modern usage, and that genus is restricted to forms from the lower and middle Albian which are closely related to the genotype *Douvilleiceras mammilatum* (Schlotheim). In Group VI, Burckhardt mostly includes species now referred to *Acanthoplites* Sinzow and some which have been assigned to *Colombiceras* Spath.

Although not so designated by Hyatt, *Cheloniceras*, as stated above, is now understood as embracing the group of *Ammonites martinii* D'Orbigny of the older workers. As such it includes 40 hitherto described species and varieties, 28 of them having been described from the eastern hemisphere and 12 from the western hemisphere. The genus is characterized by forms with coronate whorl sections having broad, rounded primary ribs which may bifurcate from prominent lateral tubercles. Usually, the tubercles are bullate and occur in three rows; one on the umbilical shoulder, another on the flanks, and a third on the ventral area. Shorter ribs rise independently on the broad venter. The latter may or may not be tuberculate but usually is furrowed or slightly excavated, especially in the youthful stages.

Cheloniceras ranges from the Bedoulian to the lower Albian (*tardefurcata* zone) but is especially characteristic and expanded in the *martinii* zone of the Gargasian.

Cheloniceras fossae Humphrey n. sp.

(Plate 14, figures 1, 5, 6)

DESCRIPTION: One rather small, well-preserved specimen showing the inner whorls represents this species.

Form discoidal; robust; moderately evolute; whorls much wider than high; increasing slowly in size, embracing preceding whorls about one-third. Whorl section depressed ovoidal, flanks flattened in youth, more strongly convex in older whorls. Umbilicus somewhat wide and deep; umbilical wall

high, inclined oblique; umbilical shoulder strongly rounded. Venter flattened convex in young stages, broadly convex with age.

This species shows a radical change in ornamentation with growth. Inner whorls and posterior part of last whorl marked by simple primary ribs. They begin high on umbilical wall, form small tuberculiform prominences on umbilical shoulder, and pass radially across flanks. On ventro-lateral margins, they form rather long, spine-shaped tubercles which shape and extend outward along umbilical wall of succeeding whorl. Above lateral tubercles, ribs thicken somewhat and form bullate swellings on each side of midline of venter, across which ribs are greatly attenuated. These early whorl ribs are rather widely separated on venter, and intervening spaces are smooth. At diameter of about 30 mm., tubercles disappear, flanks and venter become rounded, and last half of whorl is irregularly ribbed. Primary ribs start well down toward whorl suture, incline a little posteriorly across umbilical wall and then pass radially across flanks, increasing in size above and crossing venter without interruption. Rarely, a single short rib may rise independently on venter between two primaries, dying out toward ventro-lateral margins. Interspaces smooth on venter but appear to be striated on umbilical wall. Occasionally, a single thin rib will rise between primaries near the whorl suture and extend ventrally, dying out just above umbilical border. Septal suture appears to be considerably frilled but is too poorly preserved for either description or reproduction.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 22590	36	14	24	19

REMARKS: This species is characterized by its change in ornamentation and whorl section, unique among all species of *Cheloniceras* previously described from the western hemisphere. It somewhat resembles *Cheloniceras subnosocostatum* var. *pusilla* (Sinzow) (1906), pl. II, fig. 10, only) in the small diameter change in ornamentation, but the Russian form has much stronger primaries, which are first bituberculate and then trituberculate before changing into nodeless ribs on the living chamber. Also, there are usually two intercalated secondaries between each pair of long ribs on Sinzow's species. The present form is named in honor of Enrique Fossa Mancini of the Museo de La Plata, La Plata, Argentina.

DEPOSITORY: Holotype U. M. 22590 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Locality 41H8, Sierra de los Muertos, Coahuila.

Cheloniceras sanlucasensis Humphrey n. sp.

(Plate 15, figures 4, 5, 7)

DESCRIPTION: One small specimen shows the ornamentation and whorl characters and forms the basis for the following observations. The inner whorls are not visible.

Shell discoidal; depressed; whorls wider than high; embracing about one third of preceding whorls. Whorl section subhexagonal; thickest in upper third; venter flattened above; convex laterally; flanks flattened, inclined toward umbilicus. Umbilicus of average size for genus; umbilical wall low, inclined; umbilical shoulder rounded.

Sculpture consists of more or less regularly alternating primary and secondary ribs which become considerably coarser with growth. Primary ribs begin high on umbilical wall and form small, somewhat elevate tubercles on umbilical shoulders. They pass radially across flanks, increasing slightly in size, and form prominent, conical tubercles on ventro-lateral margins. From these tubercles, primaries divide into two branches which incline a little forward above margin but which are transverse, thickened, and quite prominent across mid line of venter. Posterior of the two primary branches is the thicker, being flattened and occasionally very weakly excavated at mid-venter. One unbranching primary may be seen on the holotype, and it has the same strength and behaviour across the venter as the posterior branch of a bifurcating primary. Usually one secondary is intercalated between each pair of branching primaries. Secondaries begin at umbilical shoulder but do not carry umbilical

tubercles. They form weak bullate tubercles on ventro-lateral margins, much smaller than those formed by primaries, and are about equal to anterior branch of a primary across venter. Suture lines not shown.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 22608	31	13	18.5	11

REMARKS: This species is characterized by the flattening of the venter, by the relative strength of the posterior branch of the primary ribs, and by the tuberculation of the secondaries. It seems to be most closely related to *Cheloniceras cornuelianum* (D'Orbigny) in whorl shape and ornamentation, but the French species has nontuberculate and more numerous intercalated secondaries. *C. martinii* (D'Orbigny) var. *occidentalis* (Jacob) has a uniformly convex venter on which the ribs are not inclined forward. *C. wilfridi* (Burckhardt) develops prominent ventral bullae, and the mid line of the venter is excavated in that form. *Cheloniceras paucinodum* (Burckhardt) has more numerous secondaries and an unmodified venter. *Cheloniceras nazasensis* (Burckhardt) has ventral bullae, a furrowed venter, and the secondaries do not bear tubercles.

DEPOSITORY: Holotype U. M. 22608 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Rincón de Pablillo, Sierra de San Lucas, Coahuila.

Cheloniceras cf. *C. cornuelianum* (D'Orbigny)

(Plate 14, figures 7, 9)

DESCRIPTION: One rather distorted specimen, consisting of about half an adult whorl, shows the characteristic ornamentation.

Form discoidal; apparently little embracing; increasing rapidly in width, slowly in height. Whorl section considerably higher than wide, much depressed, elongate ellipsoidal in outline; flanks flattened convex. Umbilicus moderately wide, deep; umbilical wall high, inclined; umbilical shoulder rounded. Venter wide, convex.

Surface marked by tuberculate, bifurcating primary ribs and simple, intercalated secondaries. Primaries begin on umbilical wall, form pointed clavate tubercles on umbilical border, and are prominent across flanks to ventro-lateral margin where they bear prominent clavate spines. From the latter, primaries branch into two subequal ribs which pass transversely across venter, gaining slightly in width, but diminishing in relief. Some of the bifurcating primaries may have a single rib intercalated between the two branches on venter, giving the appearance of trifurcation from marginal tubercles. Between the primaries are intercalated two or three secondary ribs. These begin generally high on flanks, although some may extend to umbilical border. They are finer than primaries on whorl sides, are non-tuberculate, and are subequal to primary ribs on venter. Venter unmarked by either tubercles or a median excavation, being evenly and broadly rounded. Septal suture not shown.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Figured specimen U. M. 22744	46?	18?.	55?	17?

REMARKS: In ornamentation, the present form agrees very closely with *Cheloniceras cornuelianum* (D'Orbigny) (1841, p. 364, pl. 112, figs. 1–2). There is a suggestion that the Mexican example may have had a flattened mid-ventral area, as is shown in D'Orbigny's figure, but this character may have been eradicated in large part by posthumous deformation of the shell. The present specimen appears to have slightly finer and less rounded ribs than in the French species, but this effect may have easily been heightened by lateral distortion after burial. In view of the state of preservation of the present example, it is not felt desirable to claim conspecificity, but the two forms clearly are very much alike and in any case very closely related.

DEPOSITORY: Figured specimen U. M. 22744 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Cañón de los Pinos, Sierra de los Muertos, Coahuila. *Cheloniceras cornuelianum* (D'Orbigny) is found in deposits of upper Aptian age in the southeast of France.

Cheloniceras sellardsi Humphrey n. sp.

(Plate 13, figures 5, 6)

DESCRIPTION: This species is represented by one specimen, which does not show the inner whorls.

Form discoidal; moderately evolute; depressed; apparently little embracing. Whorl section higher than wide, subhexagonal in outline, flanks flattened convex. Umbilicus of average size, deep; umbilical wall steep, rather high; umbilical shoulder evenly rounded. Venter flattened, somewhat excavated.

Ornamentation characterized by its irregularity. On posterior part of outer whorl, primary and secondary ribs alternate irregularly and are somewhat crowded. Primaries rise near whorl suture, form a weak bullate swelling on umbilical shoulder, pass radially across flanks and transversely across venter, where they are uniformly thickened. A faint swelling may be observed on primaries on upper third of flank. Secondaries begin on, or slightly above, umbilical shoulder and are slightly smaller than primaries across flanks and subequal to them on venter. They carry no tubercles. On anterior three-quarters of last whorl, ribs are more widely spaced. Primaries may be inclined backwards across umbilical wall, and most of them develop prominent bullae on umbilical shoulders. They pass radially across flanks, and some bear bullate swellings just below ventro-lateral margins. Primaries swell into large bullae on each side of mid line of venter and are greatly attenuated across it. Intercalated secondaries are single, nontuberculate, rise on lower third of flanks, and are much smaller than primaries and nonexcavated on venter. Two or three primaries may follow. At one place on holotype, a primary appears to bifurcate from one of the strong lateral bullae. In another case, two primaries arise from an umbilical tubercle. Septal suture unknown.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 22560	55	22	26	20

REMARKS: *Cheloniceras sellardsi* Humphrey is characterized by an increase in strength of tuberculation and by the development of a longitudinal mid-ventral furrow of the primary ribs with growth. It is further distinguished by the considerable irregularity of the ornamentation. The present form resembles *Cheloniceras caucasicum* (Anthula) (1900, p. 122, pl. XIV (XIII), figs. 1, 2, 3) in coiling and whorl shape, but the tubercles on the Caucasian species disappear with age, and it normally has two intercalated secondaries. In ornamentation, the Mexican species resembles *Cheloniceras stoliczkanum* (Gabb) (1869, p. 135, pl. XXIII, figs. 16–16a) which, however, appears to be more evolute. Gabb's species also has much coarser and more regular ribbing. The new species is named in honor of E. H. Sellards of Austin, Texas.

DEPOSITORY: Holotype U. M. 22560 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Rincón de San Gregorio, Sierra de los Muertos, Coahuila.

Cheloniceras coahuilensis Humphrey n. sp.

(Plate 14, figures 2–4)

DESCRIPTION: This species is represented by one specimen which shows a unique change in ornamentation. The inner whorls are not exposed.

Shell small; stout; whorls inflated, embracing about one-third of preceding whorls. Whorl section

depressed trapezoidal in youth, becoming higher and subovate with age. Umbilicus rather narrow for genus, somewhat deep; umbilical wall high, inclined; umbilical shoulder rounded. Venter flattened convex in youth, more broadly arched with growth; mid-ventral area flattened, giving truncated appearance.

Posterior end of outer whorl ornamented by primary ribs which are prominent across strongly divergent flanks and form pointed bullate tubercles on ventro-lateral margins. Fron the latter, primaries are inclined forward on lateral thirds of venter and are transverse and thickened across flattened mid-ventral area, on each side of which they swell slightly, but do not form tubercles. Between primary ribs are single, weak secondaries which rise in interspaces just above ventro-lateral tubercles and are non-tuberculate. With growth, whorl section becomes higher, flanks change from strongly divergent to subparallel and somewhat convex, while ventral area is strongly arched and relatively more narrow. At diameter of about 25 mm., ventro-lateral tubercles have disappeared, margins being marked only by slight swellings and a more or less abrupt change in course of ribbing. Anterior half of outer whorl marked by regularly alternating primary and secondary ribs. Primaries rise on umbilical wall and form clavate swellings on umbilical shoulder. They are transverse and prominent across flanks and inclined weakly forward across venter, being thickened and more pronounced on lightly truncated mid-ventral area. Secondaries begin at varying heights on flanks where they are much weaker than primaries. All ribs evenly spaced and subequal in size on venter. Suture lines unknown.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 22572	42	20?	28	12
Holotype U. M. 22572 (posterior end, outer whorl)	19?	9	16	?

REMARKS: This species is characterized by the change in whorl dimensions and by its ornamentation. The flattened mid-ventral area is similar to that shown by *Cheloniceras sanlucasensis* Humphrey and by *Cheloniceras cornuelianum* (D'Orbigny), but the new species is easily distinguished from those two forms by its simple, nonbifurcating ribs and by the disappearance of the ventro-lateral tubercles with age.

DEPOSITORY: Holotype U. M. 22572 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Rincón de San Gregorio, Sierra de los Muertos, Coahuila.

Cheloniceras inconstans Humphrey n. sp.

(Plate 15, figures 1–3)

DESCRIPTION: This species is represented by one small specimen which shows the inner whorls and the developmental changes in the ornamentation.

Shell discoidal, moderately evolute; whorls increasing rapidly in width, slowly in height; embracing about one-third of preceding whorls. Whorl section subovoidal in youth, flanks and venter evenly convex; in older stages whorl outline depressed ellipsoidal, flanks and venter flattened. Umbilicus of average width, somewhat deep; umbilical wall high, steep; umbilical shoulder strongly rounded.

Rounded flanks of inner whorls not costate, but carry single row of small pointed tubercles on ventro-lateral margin. On posterior part of last whorl, at diameter of about 13 mm., scarcely discernible primary ribs extend umbilically from tubercles and appear to bifurcate over venter in unaltered, very faint striae. Starting at diameter of about 18 mm., venter becomes much broader, and ornamentation becomes coarser. Primary ribs begin at umbilical border in bullate tubercles and pass prominently across narrow flanks to form large bullate swellings on ventro-lateral margins. From these marginal bullae, primaries may separate into two subequal branches which are somewhat flattened and cross broad venter transversely and without alteration. This type of sculpture continues to diameter of about 21 mm. At this diameter fifth rib from anterior end of shell is simple, carries much smaller ventro-lateral tubercle, umbilical tubercle has disappeared, and rib is much less prominent on flank. Last four ribs on outer whorl are simple, nontuberculate, extend to umbilical

shoulder, and are irregularly and rather widely separated on venter. Interspaces flat or slightly excavated, and their surface is marked by numerous, exceedingly fine striae. Septal suture not known.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 22597	25	8?	18	9
Holotype U. M. 22597 (posterior end, outer whorl)	—	6	8	—

REMARKS: This form is like no other species of *Cheloniceras* known to the writer in the development of the ornamentation, the three stages described above taking place through very small increases in diameter. *Cheloniceras inconstans* Hunphrey is characterized further by the change in whorl shape and by the extreme width in relation to height of the anterior portion of the outer whorl.

DEPOSITORY: Holotype U. M. 22597 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. First arroyo to the east from Rincón de Las Boquillas on the north flank of the Sierra de Las Boquillas de Santo Toribio, Coahuila.

Cheloniceras sp. *A*

(Plate 14, figures 8, 10)

DESCRIPTION: The following notes are based on one fragmentary and distorted example, which shows the characteristic ornamentation. The inner whorls are imperfectly preserved.

Form discoidal; much depressed; whorls apparently increasing rapidly in size, embracing preceding whorls by about one-third. Whorl section much wider than high, outline subhexagonal in youth to depressed ovoidal with age; flanks narrow, slightly convex, inclined toward umbilicus. Umbilicus of average size; umbilical wall steep, almost perpendicular; umbilical shoulder rounded. Venter wide, flattened convex, somewhat excavated along the mid line.

Ornamentation of inner whor s poorly shown, but strongly hexagonal whorl section appears to be outlined by prominent primary ribs which bear bullae on each side of an excavated mid-ventral area. Bullate ventro-lateral tubercles probably present at early stage as well as some much finer, intercalated secondary ribs. Outer whorl ornamented by trituberculate, bifurcating primaries alternating with two or three intercalated secondaries. Primaries begin on umbilical wall, form small pointed tubercles on umbilical shoulder, pass radially across flanks, and form bullate tubercles at ventro-lateral margin. On posterior part of outer whorl, one primary bifurcates at umbilical tubercle. Posterior branch much the coarser of the two, carrying thick bullae both on ventro-lateral margins and on each side of midline of venter. Anterior branch less prominent and shows only slight thickenings where bullae are formed by the other branch. On anterior part of outer whorl, primaries bifurcate at ventro-lateral bullae, which become spine-shaped and much elongate with growth. Posterior branch, as before, is usually much coarser than anterior branch and develops strong bullae on each side of excavated mid-ventral area. With age, the two branches appear to be more nearly subequal, and ventral bullae decrease in prominence. Secondary ribs rise near umbilical shoulder, and two of them seem to unite in small umbilical tubercle at one place on last whorl. They carry neither ventro-lateral nor ventral tubercles, are not excavated on mid line of venter, and, at least on posterior part of outer whorl, are much finer than primaries. With growth of shell, all ribs tend to become subequal on venter. Septal suture not shown.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
U. M. 22683 (anterior end)	55?	22?	59?	25?
U. M. 22683 (posterior end, outer whorl)	—	19	37	—

REMARKS: In whorl shape and ornamentation, this form resembles *Cheloniceras martinii* (D'Orbigny) var. *orientalis* (Jacob) (D'Orbigny, 1840, pl. 58, figs. 7–8 only), but Jacob's variety has a

narrower section, a much more furrowed venter, and lacks the umbilical tubercles. *Cheloniceras martini* (D'Orbigny) var. *occidentalis* (Jacob) (D'Orbigny, 1840, pl. 58, fig. 9 only) has a uniformly rounded venter, and the primaries appear to trifurcate. *Cheloniceras stoliczkanum* (Gabb) (1869, p. 135, pl. XXIII, figs. 16–16a) has three rows of tubercles and a furrowed venter, but the ribs do not bifurcate, at least in the adult whorls and the whorl section appears to be relatively much higher than in the present form. *Cheloniceras subnodosocostatum* (Sinzow) (1906, p. 175, pl. II, figs. 1–8) has much coarser ribbing of which the primaries bifurcate from ventro-lateral tubercles in youth and rarely from umbilical tubercles on the adult whorls. The Mexican example is somewhat similar to one of the forms figured by Riedel (1937, pl. V, figs. 17–19 only) as *Cheloniceras* juv. sp. aff. *cornuelianum* (D'Orbigny). The Colombian species, however, shows little furrowing of the primaries, the ventral area being quite evenly convex. The true *Cheloniceras cornuelianum* (D'Orbigny) (1840, pl. 112, figs. 1–2) has a flattened mid-ventral area, on which the primaries are not excavated.

DEPOSITORY: Figured specimen U. M. 22683 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Puerto Las Palmas, Sierra del Caporal, Coahuila.

Genus *Megatyloceras*[2] Humphrey n. gen.

GENOTYPE: *Douvilleiceras coronatum* ROUCHADZE, Les ammonites aptiennes, p. 195, pl. III, fig. 4, text figs. 12–13, 1933.

This new generic name is proposed for a group of cheloniceratid ammonites, characterized by an extreme width of coronate whorl section, deep umbilicus, high and abrupt umbilical wall, and an ornamentation of strong primary and secondary ribs, possessing but one row of prominent lateral bullae in the adult stages. The ribs may or may not bi- or trifurcate from the bullae, and they cross the wide venter without interruption.

As defined, *Megatyloceras* n. gen. includes forms previously referred to the "*group* of *Douvilleiceras hambrovii* (Forbes)" by Rouchadze (1933, p. 196) and in part to what Burckhardt (1925, p. 26) called the "group of *Douvilleiceras ricordeanum* (D'Orbigny)", although he included in that group the genotype species of *Cheloniceras* Hyatt. Six species of ammonites, five of them heretofore variously assigned to either *Cheloniceras* or *Douvilleiceras* and one described below as new, are here referred to this new genus. They are as follows:

Douvilleiceras coronatum ROUCHADZE, 1933, p. 195, pl. III, fig. 4, text figs. 12–13, and 1938, p. 178, pl. I, fig. 7, pl. II, fig. 1.

Ammonites hambrovii FORBES, 1845, p. 345, pl. III, fig. 4.

Cheloniceras hambrovii (Forbes) var. *horrida* SPATH, 1930, p. 444.

Ammonites ricordeanus D'ORBIGNY, 1850, p. 199, pl. VIII, fig. 8.

Megatyloceras casei Humphrey n. sp., pl. 15, fig. 6, pl. 16, fig. 1, pl. 17, fig. 1.

?*Cheloniceras crassum* SPATH, 1930, p. 449, pl. XV, fig. 6.

Megatyloceras differs from *Cheloniceras* in the absence of a ventral furrow or excavation, in the absence of ventral tuberculation, in the fewer rows of tubercles, and in having a far greater width of whorl section in proportion to whorl height. *Cheloniceras* is thus restricted to the *martinii-royerianum-subnodosocostatum* groups, to which most other described species of that genus can be referred.

Megatyloceras appears to be an exclusively Aptian genus, the cited forms having been described either from the Bedoulian or the Gargasian substages. *Megatyloceras coronatum* (Rouchadze) is here designated as the genotype.

Megatyloceras casei Humphrey n. sp.

(Plate 15, figure 6; Plate 16, figure 1; Plate 17, figure 1)

DESCRIPTION: This species is represented by one large internal cast on which the inner whorls are imperfectly shown.

Form discoidal, depressed, evolute. Whorl section coronatiform, much wider than high, appar-

[2] *Megas*, large; *tylos*, knob; *ceras*, horn.

ently embracing only about one-fifth of the preceding whorls. Flanks narrowly convex, venter broadly rounded. Umbilicus deep, rather wide; umbilical wall high, steeply inclined.

Shell ornamented by irregularly alternating primary and secondary ribs. Primaries begin on umbilical wall and form exaggerated lateral bullae from which, on posterior part of outer whorl, two or three smaller rounded ribs may branch. One secondary may rise independently on broad venter between branching primaries. All ribs cross venter transversely without alteration, being somewhat irregularly spaced and subequal in size. On anterior portion of outer whorl, bifurcation from large bullae is rare, and two secondaries may be present between two simple primaries. On inner whorls there is a suggestion that the bullae are represented by small, double nodes and that whorl height may be relatively greater. Suture lines not shown.

D mensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 21865	176	68	150	85

REMARKS: This species strongly resembles *Megatyloceras coronatum* (Rouchadze) (1938, pl. I, fig. 7), but the Russian species has coarser and less numerous bullae and a proportionately narrower whorl section. *Megatyloceras casei* Humphrey is characterized by an extremely wide whorl section, by the number and prominence of the lateral bullae, and by the irregularity of the ribbing on the venter. The new species is named in honor of Professor Emeritus Ermine Cowles Case of the University of Michigan, Ann Arbor, Michigan.

DEPOSITORY: Holotype U. M. 21865 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Sierra del Rosario, Durango, Mexico. Collected by Lewis B. Kellum.

Genus *Colombiceras* Spath 1923

GENOTYPE: *Ammonites crassicostatus* D'Orbigny, 1841, Pal. Fr. Terr. Cret., I, pl 197, pl. LIX, figs. 1–4, 1840–1841.

In proposing *Colombiceras*, Spath (1923b, p. 64) gave no formal diagnosis of the genus. He included it in his new family Cheloniceratidae Spath, along with *Procheloniceras*, *Cheloniceras*, *Pedioceras*, and *Diadochoceras*, stating (p. 64, footnote), "This is a derivative of *Cheloniceras martini*, D'Orbigny, and produces *Parahoplites*-like forms (*A. alexandrinus*, D'Orbigny)."

As interpreted by the writer, *Colombiceras* includes only those forms closely related to the genotype. As such, the genus is composed of discoidal, rather evolute species, characterized by a subquadrate whorl section with flattened to subrounded flanks and venter. The sculpture consists of unequal, nearly straight ribs which are flattened and steep-sided, having a wedge shape in section. Most of them start from the umbilical wall; some bifurcate from pointed tubercles near the umbilicus or below mid flanks, especially in the young stages. There may be intercalated secondaries, and all ribs are strengthened on the upper flanks and over the venter. The cuneiform nature of the ribs seems to be the most characteristic feature of the ornamentation. Species which may be referred to the genus in this restricted sense are as follows:

Ammonites crassicostatus D'Orbigny, 1841, p. 197, pl. LIX, figs. 1–4.

Dufrenoya robusta SCOTT, 1940, p. 1025, pl. LXIII, figs. 8–9.

Acanthoplites tobleri (Jacob) var. *discoidale* SINZOW (1907, p. 487, pl. V, figs. 17–20); see also Riedel, (1937, p. 49).

Acanthoplites subtobleri KASANSKY, 1914, p. 75, pl. III, fig. 57 only.

Acanthoplites sinzowi KASANSKY, 1914, p. 73, pl. III, fig. 53 only.

Parahoplites sp. ind. No. 1 BURCKHARDT, 1925, p. 23, pl. III, figs. 11–13.

C. spathi Humphrey n. sp. (Plate 18, figures 7, 8).

However, another group of interrelated forms has been referred to *Colombiceras* by Spath, Basse, and Riedel. It includes the following forms:

Parahoplites tobleri JACOB AND TOBLER, 1906, p. 11, pl. II, figs. 4–6.

Ammonites karsteni (Marcou) = *Ammonites acostae* KARSTEN, 1858, p. 111, pl. V, fig. 1; see also BASSE (1928, p. 136, pl. VIII, fig. 5).
Ammonites treffryanus KARSTEN, 1858, p. 109, pl. IV, figs. 1a–b; see also RIEDEL (1937, p. 50).
Colombiceras aff. *C. tobleri* (Jacob) RIEDEL, 1937, p. 51, pl. VIII, figs. 23–24.
Acanthoplites subpeltoceroides SINZOW, 1907, p. 484, pl. IV, figs. 3–4; pl. V, fig. 16.

These species have whorl sections that are generally higher than wide and more ovate than subquadrangular. The more or less flexuous ribs thicken considerably over the venter but do not have the steep sides and flat-topped cuneiform appearance of the group of *crassicostatus*. Tubercles are not present, at least on the adult whorls. This group appears to be somewhat intermediate between *Colombiceras* (sensu stricto) and *Acanthoplites* (sensu stricto). Certainly some of the above-listed species have more in common with acanthoplitids like *Acanthoplites abichi* (Anthula) than they do with *Colombiceras crassicostatum* (D'Orbigny).

According to Kilian (1913, p. 292, 350), the genotype of *Colombiceras* apparently is restricted to the *martinii* zone of the Gargasian, while *C. tobleri* (Jacob) is common in the *subnodosocostatum* zone. World-wide occurrences of the genus suggest that it is probably restricted to rocks of upper Aptian age.

Colombiceras spathi Humphrey n. sp.

(Plate 18, figures 7, 8)

DESCRIPTION: One somewhat distorted specimen represents this species. The inner whorls are not shown.

Shell discoidal; compressed; moderately evolute; embracing about one-fourth of preceding whorls. Whorl section subquadrate on early part of outer whorl, flanks and venter flattened-convex; anterior part of outer whorl distorted; higher than wide, sides subparallel, venter narrow, somewhat flattened. Umbilicus rather wide for genus, shallow; umbilical wall low, steep; umbilical shoulder strongly rounded.

Surface of shell marked by rather irregularly alternating primary and secondary ribs. Primaries rise on umbilical wall, quickly gain in prominence on umbilical shoulder and pass radially or very slightly flexuous across flanks, widening rapidly toward venter. On posterior part of last whorl, several primaries bifurcate low on flanks or from tubercle-like swellings on umbilical shoulder. Two or more primaries may follow each other or alternate with single secondaries. The latter begin low on flanks and may simulate bifurcation by rising very close to an adjoining primary near umbilicus. On last half of outer whorl, there is rather regular alternation of simple primaries and quite long secondary ribs. On upper third of flanks, all ribs present typical flat-topped, steep-sided appearance characteristic of the genus. Ribs widest and have most relief on venter, where they are evenly spaced, equal in size, and transverse. Suture lines unknown.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 24298	50	19	11?	18
Holotype U. M. 24298 (posterior end, outer whorl)	27?	10	9	15?

REMARKS: At equivalent diameters, the new species is not unlike the larger of the two forms of *Ammonites crassicostatus* D'Orbigny figured by that author (1841, pl. LIX, figs. 1–2). It differs, however, from D'Orbigny's species in having more numerous secondary ribs and in its less truncated venter. *Colombiceras spathi* Humphrey is close to *C. subtobleri* (Kasansky) (1914, pl. III, fig. 57 only), but the Daghestan form appears to be more involute, and bifurcation of its primary ribs takes place on the upper third of the flanks. *C. sinzowi* (Kasansky) (1914, pl. III, fig. 53 only) is more involute and has many fewer secondaries than the present form. This species is dedicated to L. F. Spath of the British Museum (Natural History), foremost student and contributor to the knowledge of Mesozoic Cephalopoda.

DEPOSITORY: Holotype U. M. 24298 in the University of Michigan, Museum of Paleontology.
OCCURRENCE: La Peña formation. Rincón de los Potreritos, Sierra del Caporal, Coahuila.

Family DESMOCERATIDAE, Zittel

Genus *Uhligella*, Jacob 1907 emend. Spath, 1923

GENOTYPE: *Ammonites sequenzae* COQUAND in SAYN, Djebel Ouach, p. 40, pl. II, figs. 10a–b, 1896.

In the absence of data regarding the septal sutures, assignment to *Uhligella* of the four species described below must be regarded as tentative. The extensive discussion by Spath (1923b, p. 31–39) of the nature and interrelations of the Lower Cretaceous Desmoceratidae indicates how misleading identifications may be which are based on the striking and superficial resemblances between the various genera now included in that family. The new species herein described have been compared, on the basis of coiling, whorl dimensions, and ornamentation, with previously described species of the group of *Uhligella zurcheri* Jacob and *Ammonites sequenzae* Coquand, to which the genus *Uhligella* has been restricted by Spath (1923b, p. 38).

Uhligella reesidei Humphrey n. sp.

(Plate 18, figures 3, 4)

DESCRIPTION: This species is represented by one fairly complete inner mold.

Shell discoidal; narrow, flattened; moderately involute, whorls embracing about two-thirds of preceding whorls. Whorl section subellipsoidal, thickest in lower third, flanks flattened, somewhat convergent. Umbilicus somewhat broader than in genotype species; umbilical shoulder abrupt; umbilical wall perpendicular, fairly high, slightly inclined on anterior part of outer whorl. Venter narrowly rounded in youth, squarish and much wider on last part of outer whorl, which is somewhat distorted.

The somewhat irregular ornamentation consists of flexuous well-marked flanges, constrictions, and finer intercalated ribs. Flanges are relatively narrow but well defined and prominent. They rise on lower third of flanks but do not extend to umbilical shoulder. They curve convex forward across lower flanks and are convex backward across upper half of flanks, passing across venter where they are slightly arcuate forward. Flanges do not increase greatly in size on anterior part of last whorl but are more widely spaced. Their posterior edges are bounded by shallow constrictions which are about equal in width to flanges, but they die out before the latter on lower third of flanks. Constrictions more prominent on posterior part of last whorl, becoming flattened and barely perceptible anteriorly. One or two, rarely three, fine shorter ribs intercalated between adjoining flanges, rising in interspaces at, or slightly below, middle of flanks. They are strongest on upper half of whorl sides, being much less prominent across venter. Exposed lower flanks of inner whorls are almost entirely smooth. Septal suture not known.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 22667	34	15	9	9

REMARKS: *Uhligella reesidei* Humphrey is characterized by the decrease in prominence of the intercalated ribs across the venter and by the failure of the flanges to extend to the umbilical shoulder. The flanges are more widely separated on the anterior portion of the outer whorl in the present form, distinguishing it from *Uhligella jacobi* Burckhardt and from *Uhligella aguilerae* Burckhardt, in both of which the flanges become crowded anteriorly. Also, in both of Burckhardt's species, the flanges rise on the umbilical shoulder, while in one (*U. jacobi*) the intercalated costae bifurcate and in the other (*U. aguilerae*) they anastomose. "*Uhligella*" *mexicana* Burckhardt is, in all probability, a *Beudanticeras* and has nothing in common with the present species. *Uhligella latecostata*

Riedel (1937, pl. V, figs. 1–2) has a much thicker whorl section than the new form and is further distinguished by the extreme width of the flanges on its outer whorl. In degree of involution and in the whorl section, the new species closely resembles the Colombian form figured by Riedel (1937, pl. IV, figs. 12–13) as *Uhligella zurcheri* Jacob and Tobler but the South American species has a rounded umbilical wall, and the intercalated costae are longer and more numerous. *Uhligella rebouli* Jacob (1907a, pl. IV, figs. 1–5) has a much coarser sculpture and develops nodes in the umbilical region. This species is named in honor of J. B. Reeside, Jr. of Washington, D. C.

DEPOSITORY: Holotype U. M. 22667 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Rincón de los Potreritos, Sierra de los Muertos, Coahuila.

Uhligella mullerriedi Humphrey n. sp.

(Plate 18, figures 10, 13)

DESCRIPTION: One incomplete example represents this species, whose unique ornamentation merits description.

Form discoidal; involute; whorls embracing about half (?) of preceding whorls. Whorl section subovoidal, higher than wide, thickest just above umbilical shoulder, flanks gently inclined toward venter. Umbilicus narrow, rather shallow; umbilical wall inclined, oblique; umbilical shoulder rounded. Venter relatively narrow, rounded.

Sculpture consists of irregularly alternating, long and short flanges, constrictions, and short intercalated ribs. Every other flange is long, rising near umbilical shoulder and directed forward on lower flanks, where it forms a transversely elongate swelling. On upper half of flanks, long flanges curve backward and are more attenuated, bending forward again and passing unaltered across arched venter. Short flanges arise at or above mid flanks, or may occasionally extend much attenuated to lower third of flanks. Across the venter they curve forward parallel to long flanges and may be slightly more prominent than the latter. Constrictions are shallow and bound flanges along their posterior edges. They are most pronounced on posterior part of outer whorl, being flattened and little prominent anteriorly. One or two short intercalated ribs rise on upper third of flanks and are subequal to flanges on venter. Commonly the rib preceding a flange is more prominent across venter than flange itself. Septal suture not known.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 16479	34.3	11	10	11

REMARKS: *Uhligella mullerriedi* Humphrey is characterized by the alternation of long and short flanges and by the umbilical swellings of the former. In form and ornamentation it somewhat resembles *Uhligella rebouli* Jacob var. (1907a, p. 33, pl. IV, fig. 5a only), but Jacob's unnamed variety shows a much coarser costation, and there is no alternation of the flanges. This species is named in honor of Frederick Müllerried of Mexico City, lifelong student of Mexican geology and paleontology.

DEPOSITORY: Holotype U. M. 16479 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: Upper member of the La Peña formation. Locality 4, horizon B of Ralph W. Imlay, Sierra de Parras, Coahuila.

Uhligella riedeli Humphrey n. sp.

(Plate 18, figures 1, 2)

DESCRIPTION: This form is represented by one fairly complete specimen. Cemented to it by the dark-gray limestone matrix is a young whorl fragment belonging to the same species.

Shell discoidal; moderately involute, whorls embracing about half of preceding whorls. Whorl section subovoidal, somewhat higher than wide, flanks evenly convex, thickest in lower third. Um-

bilicus narrow, rather deep; umbilical shoulder sharply rounded; umbilical wall steep, relatively high. Venter narrowly arched, broadening anteriorly.

Shell marked by flanges, grooves, and few intercalated secondary ribs. Flanges rise on umbilical shoulder, enlarging rapidly and curving slightly forward on lower flanks. On upper flanks they maintain their strength and curve slightly backward, bending weakly arcuate forward again on venter which they cross without alteration. Flanges rather fine on posterior part of last whorl, increasing in width and relief anteriorly. Grooves, well defined but rather shallow, bound posterior edge of flanges, curving backward and disappearing on upper side of umbilical shoulder. Grooves deeper and wider on older part of whorl and generally are most pronounced on venter. Intercalated secondary "ribs" usually consist of single ridges which bound posterior side of grooves. They are usually less prominent than flanges and die out on lower third of flanks but may be subequal to flanges on anterior part of outer whorl. Rarely, another rib about half the size and prominence of a flange may be intercalated between pre-groove ridge and preceding flange. The small specimen indicates that this ornamentation still obtains at a diameter of 13 mm. Suture lines not known.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 20198	35.6	15	12	9

REMARKS: *Uhligella riedeli* Humphrey is characterized by the paucity of costation between the flanges and by its narrow and deep umbilicus. The whorl section is wider and more depressed than in either of the two preceding species, and the shell has a decidedly inflated appearance. The whorl section is not unlike that figured for *Melchiorites emerici* Rasp. var. *media* Riedel (1937, pl. XII, fig. 7), but the Colombian variety has numerous bundled costae between the constrictions. The present species is named in honor of Leonhardt Riedel of Germany, contributor to the paleontology of the Aptian in Colombia.

DEPOSITORY: Holotype U. M. 20198 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. About 1 mile N. 2° W., from the house at El Mulato Ranch, Río Nazas, Durango.

Uhligella jacobi Burckhardt

(Plate 18, figures 5, 6, 9)

1925 *Uhligella jacobi* BURCKHARDT, Río Nazas, p. 11, pl. II, figs. 7–10.
1936 *Uhligelli jacobi* KELLUM, Mountains West of Laguna District, p. 1039.

DESCRIPTION: The following is a translation of Burckhardt's original description:

"Shell discoidal, flattened, and evolute. The whorls embrace as much as two-thirds on the outer part of the last whorl, being more embracing posteriorly. The flanks are very little convex, even flattened; venter narrow, rounded. The flanks descend into an umbilical wall which is perpendicular but not very high, forming an obtuse angle on the umbilical border. Also between the flanks and the venter there appears to exist an obtuse angle but it is not impossible that this is nothing more than the effect of a slight compaction suffered by the shell.

"Transverse section elongate, much higher than wide, with the greatest thickness near the umbilical region, somewhat narrowed toward the venter. The umbilicus is narrow but it widens somewhat with age.

"The ornamentation on the posterior part of the outer whorl consists of quite prominent and separated flexuous flanges ("bourrelets") and of fine flexuous intercalated costae. The flanges rise on the border of the umbilicus, are directed somewhat anteriorly on the lower part of the flanks and posteriorly on their upper part. They are arched slightly forward in passing unaltered over the venter. Behind the flanges are seen grooves which are but little marked. In the interspaces between the flanges two or three intercalated costae are seen which generally begin toward the upper third, but at times (especially the middle one if three are present) also toward the middle third of the flanks. These intercalated costae are much finer than the flanges and, like them, pass unaltered over the venter, on which they are slightly arched foreward.

"On the last part of the outer whorl there is a change in ornamentation. The flanges are less

separated there and more resemble the intercalated costae. Between the flanges one to three intercalated costae may be observed, some of them having a tendency to unite by twos. The majority of them are restricted to the upper third of the flanks, but a few of them extend to the lower third of the flanks, disappearing gradually. Occasionally, a not very clear bifurcation of the flanges is observed toward the middle of the flanks. Such cases are more the result of the end of an external rib approaching the posterior margin of a flange, thus simulating a bifurcation of the latter. The bounding grooves of the flanges are scarcely perceptible."

REMARKS: Three examples in the writer's collections from the Sierra de San Lucas appear to be very close to the form figured and described by Burckhardt. One of them is almost entire but somewhat distorted. The other two are but indifferently preserved whorl fragments. The largest specimen here figured (Pl. 18, figs. 5, 6) differs from Burckhardt's specimen in being almost smooth on the innermost whorls and in having a much thinner whorl section. Since these differences may be due to distortion and poorness of preservation, it is not felt desirable to introduce a new varietal name for the Coahuila examples. This species is characterized by the angular umbilical shoulder, the subequal development of ribs and flanges on the outer whorls, and by the apparent bifurcation of the intercalated ribs.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype	44	21.5	13	10
Hypotype U. M. 24260	41	18	9.8	10.5
Hypotype U. M. 22607	?	24	11	?

DEPOSITORY: Holotype in the collections of the Instituto Geológico de México, México, D. F. Hypotypes U. M. 24260 and U. M. 22607 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: Holotype from La Peña formation (= "Capas con *Douvilleiceras*" of Burckhardt) of Río Nazas, Durango; Loma Verde, locality 3 of Burckhardt. Hypotypes from the La Peña formation, Rincón de Pablillo, Sierra de San Lucas, Coahuila.

Genus *Pseudohaploceras* Hyatt 1900

GENOTYPE: *P.* (*Hapl.*) *liptoviense*, UHLIG sp. (cited by HYATT, 1900, p. 570) (= *Haploceras liptoviensis* (Zeuschner) UHLIG, Wensdorfer Schichten, p. 229, pl. XVII, figs. 9, 16–18, pl. XVIII, figs. 1, 3, 5, 6), 1883.

This genus was not admitted by Kilian (1907–1913, p. 262–263) who considered it as a section of *Puzosia* and derived in the Hauterivian from the group of "*Puzosia*" *ligata* (D'Orbigny). Spath (1923b, p. 34) accepts *Pseudohaploceras* for the "*liptoviense-hopkinsi*" groups and attributes to it an upper Barremian-Aptian range. According to Spath, *Callizoniceras* is close to *Pseudohaploceras* but has a simple suture line. The septal sutures are not shown on the two forms referred below to *Pseudohaploceras*?. They might equally well have been assigned to *Callizoniceras*? except that in ornamentation they more closely resemble *P. liptoviensis* (Zeuschner) than they do the type of Spath's genus, *Callizoniceras hoyeri* (v. Koenen).

Pseudohaploceras? *hedbergi* Humphrey n. sp.

(Plate 18, figures 11, 12)

DESCRIPTION: This species is represented by one somewhat distorted specimen.

Shell discoidal; moderately evolute; embracing about one-third of preceding whorls; increasing gradually in height and width. Whorl section compressed ovoidal, higher than wide, flanks evenly convex in youth, flattened and somewhat convergent on older whorls. Umbilicus rather small, widening with age; umbilical shoulder rounded; umbilical wall moderately inclined. Venter evenly rounded in youth, more narrowly arched on anterior part of whorl.

Outer whorl marked by 11 or 12 rather widely separated flanges which begin on flanks near um-

bilical shoulder, pass either radially or very slightly flexuous across flanks, and curve weakly forward and become prominent on narrowed venter. Posterior to flanges are flattened, poorly defined, and rather wide constrictions. Between flanges 5 to 7 intercalated fine costae rise singly from interspaces or by twos and threes from transversely elongate swellings located at, or just below, middle of flanks. These costae are secondary and parallel to flanges and like them cross venter without interruption. Septal suture not known.

Dimensions in mm. are as follows:

	Diameter	*Whorl height*	*Whorl thickness*	*Width of umbilicus*
Holotype U. M. 22430	41	17	9	12

REMARKS: In the absence of the suture lines, this desmoceratid species is referred with question to *Pseudohaploceras*. The Mexican species resembles the forms illustrated by Uhlig (1883, pl. XVII, figs. 17–18; pl. XVIII, figs. 1, 3, 5–6) as *Ammonites liptoviensis* Zeuschner but differs in having more flanges per whorl and fewer intercalated costae. It is more widely umbilicate than the example figure by Kellum (1936, pl. VII, fig. 13) as *Puzosia* sp. gr. of *P. liptoviensis*, which has a thicker and more robust whorl section and which is likely a good species of *Puzosia* sensu stricto. Spath (1923b, p. 34, 45) restricts *Puzosia*, whose type comes from the upper Gault, to the *planulata* group. *Pseudohaploceras? hedbergi* Humphrey occurs with *Dufrenoya*, *Cheloniceras*, and *Colombiceras* and is probably of early Gargasian (late Aptian) age. The new species is named in honor of Hollis D. Hedberg of New York.

DEPOSITORY: Holotype U. M. 22430 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Puerto Las Palomas, Sierra del Caporal, Coahuila.

Pseudohaploceras? sp.

(Plate 18, figures 14, 15)

DESCRIPTION: One distorted whorl fragment in the writer's collections is somewhat similar to the form described by Burckhardt (1925, p. 9, pl. II, fig. 1) from near El Mulato Ranch, Durango, as *Puzosia* aff. *matheroni* (D'Orbigny).

The form described here was evidently much higher than wide and but little embracing. Venter seems to have been narrowly arched; umbilical shoulder rounded; umbilical wall inclined and not very high.

Surface of shell marked by numerous flanges and intercalated secondary ribs. Flanges start at umbilical shoulder, are slightly flexuous, and enlarge toward venter which they cross without interruption, curving very slightly forward. They are bordered posteriorly by flattened, ill-defined grooves. Between adjoining flanges are four less prominent, intercalated ribs, of which the third one after a flange is the longest, extending parallel to flanges to umbilical border but being much less prominent on lower third of flanks. Other three ribs subequal in length, rising on middle or upper third of flanks. Apparent bifurcation may result when shorter ribs approach each other or a flange. Septal suture not known.

REMARKS: The present form is much larger than *Pseudohaploceras? hedbergi* Humphrey, while the intercalated costae are less numerous, and the flanges extend to the umbilical shoulder. The ribbing is more flexuous than in *Puzosia* aff. *P. matheroni* (D'Orbigny) Burckhardt sp. although this feature may be due in part to posthumous distortion. Also, Burckhardt's species has more intercalated ribs than does the Coahuila example.

DEPOSITORY: Figured specimen U. M. 24261 in the University of Michigan, Museum of Paleontology.

OCCURRENCE: La Peña formation. Puerto Las Palomas, Sierra del Caporal, Coahuila.

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(Natural size)

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   Lateral view of holotype U. M. 15886 from Puerto San Isidro, Durango, Mexico. (Retouched photograph furnished through the courtesy of A. K. Miller of Iowa City, Iowa.)

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PARACYMATOCERAS

1 2

PARACYMATOCERAS

PLATE 5.—*PARACYMATOCERAS*

(All figures natural size)

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Ventral and apertural views of holotype U. M. 15886, from Puerto de San Isidro, Durango, Mexico. (Retouched photographs furnished through the courtesy of A. K. Miller of Iowa City, Iowa).

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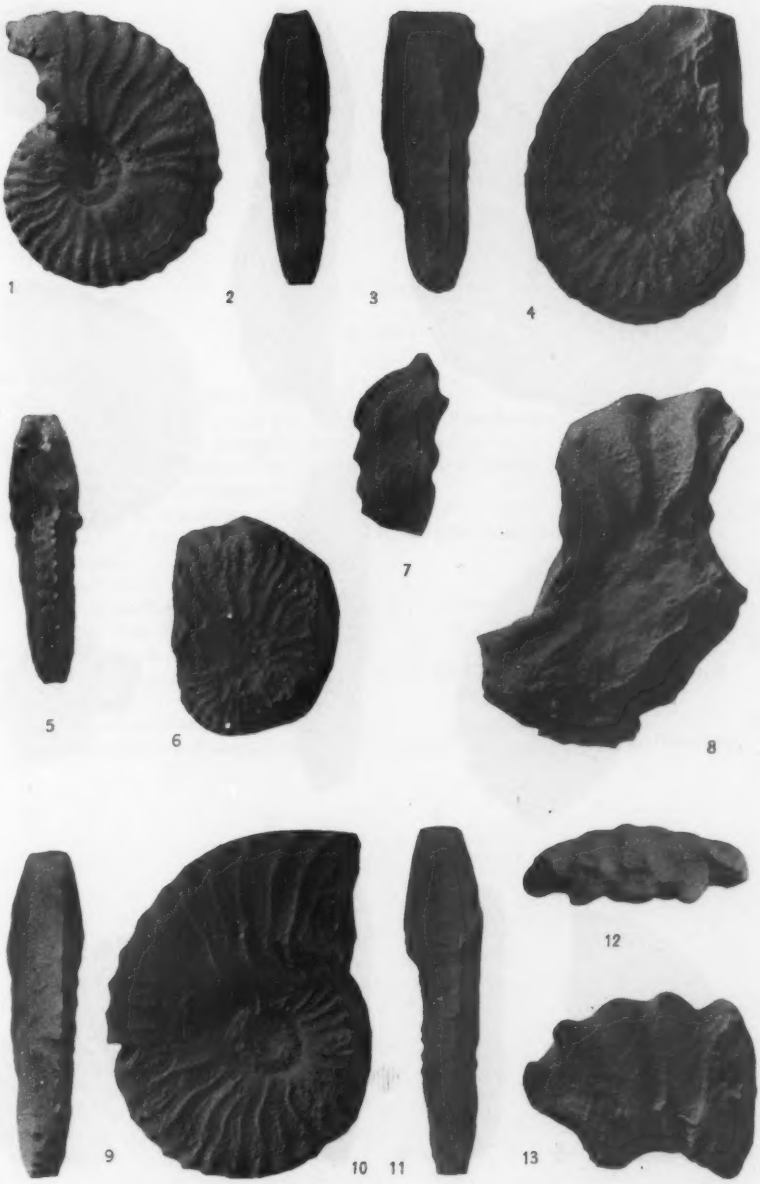

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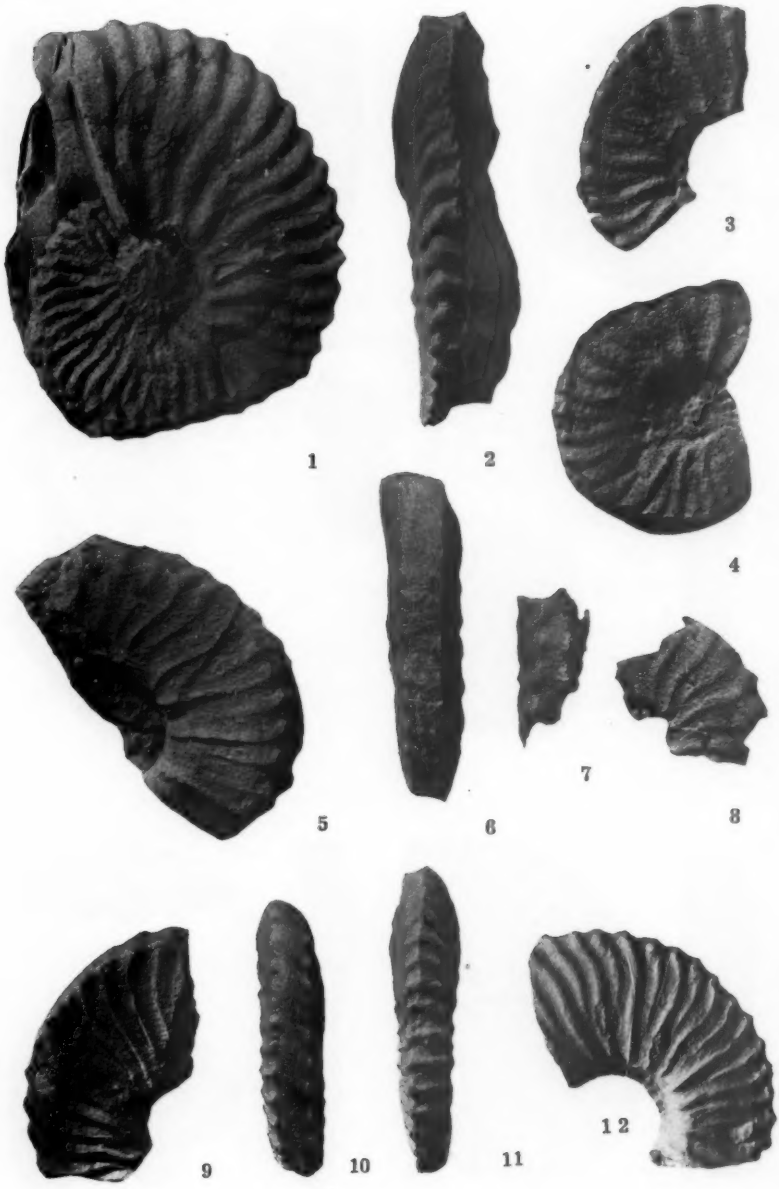

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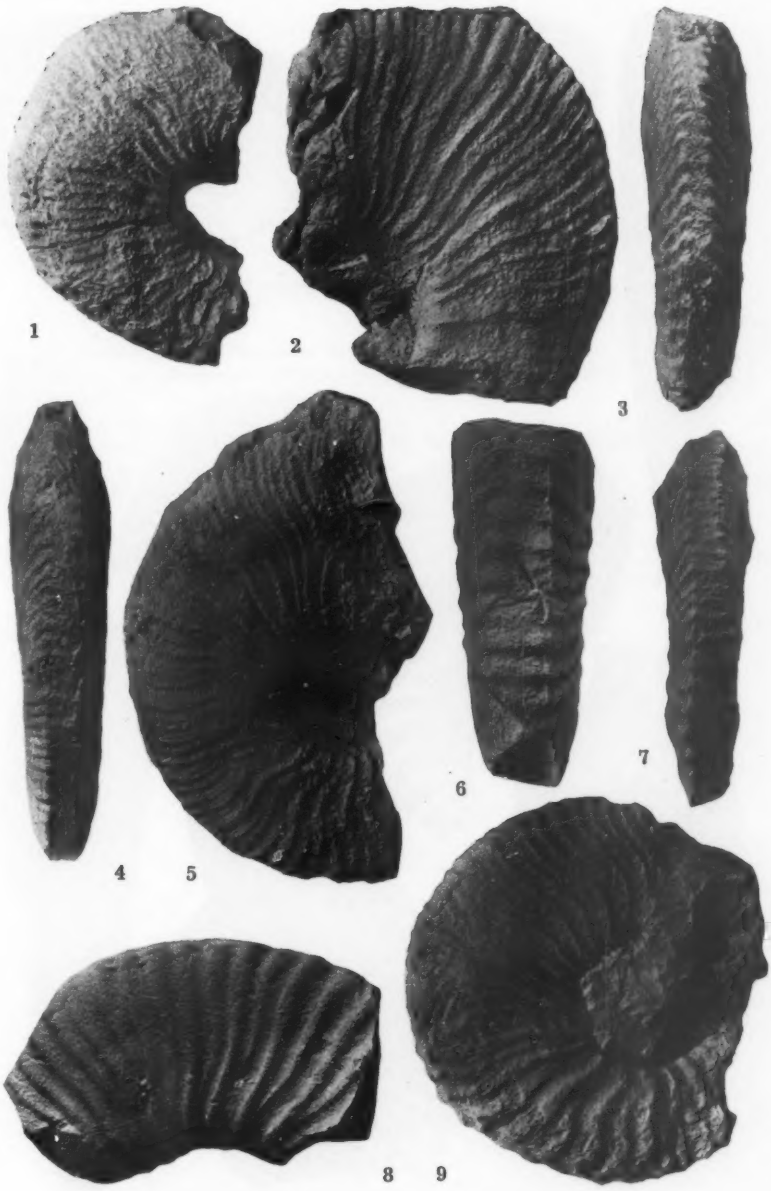
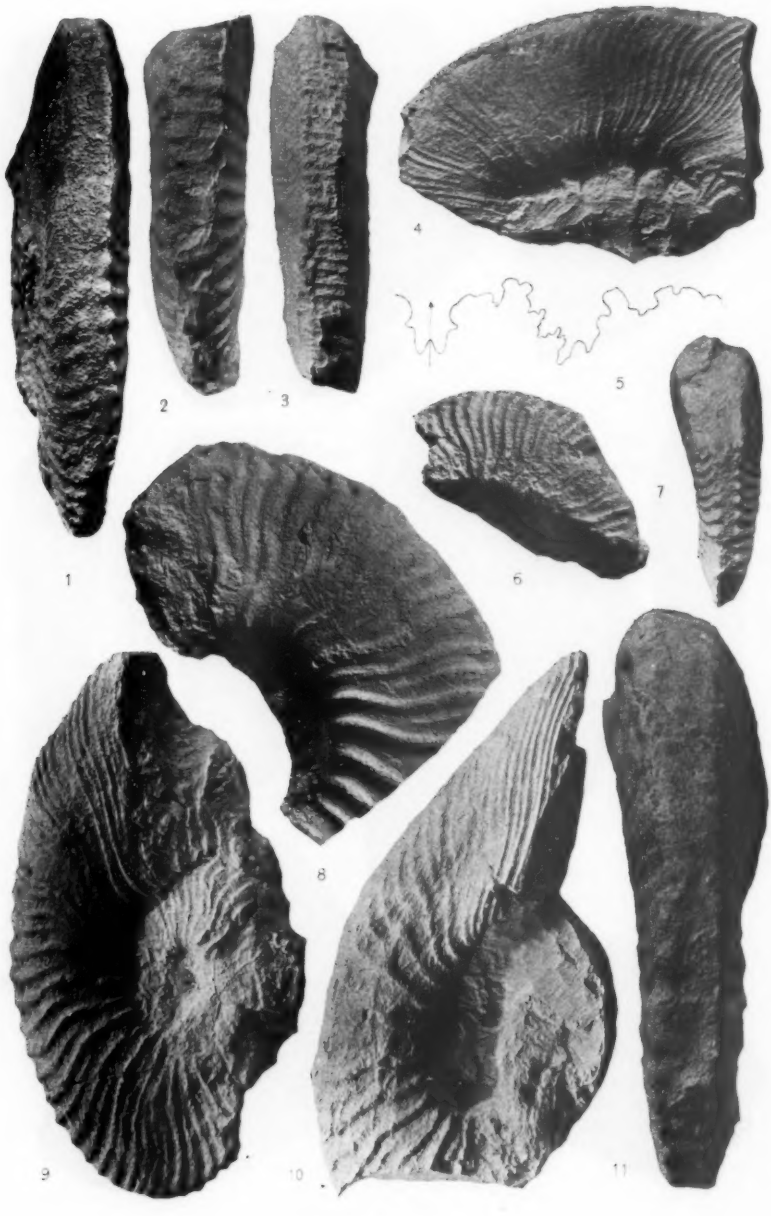


BURCKHARDTITES



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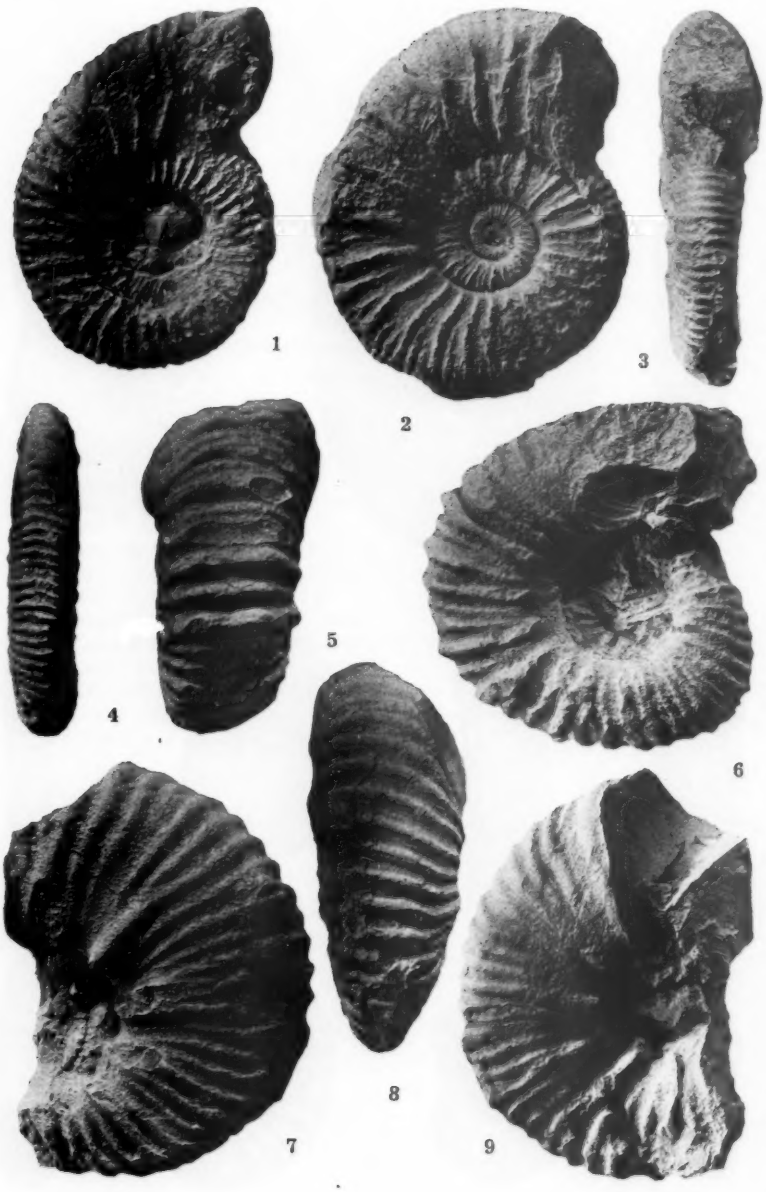

ACANTHOPLITES?, *CHELONICERAS*, and *HYPACANTHOPLITES*

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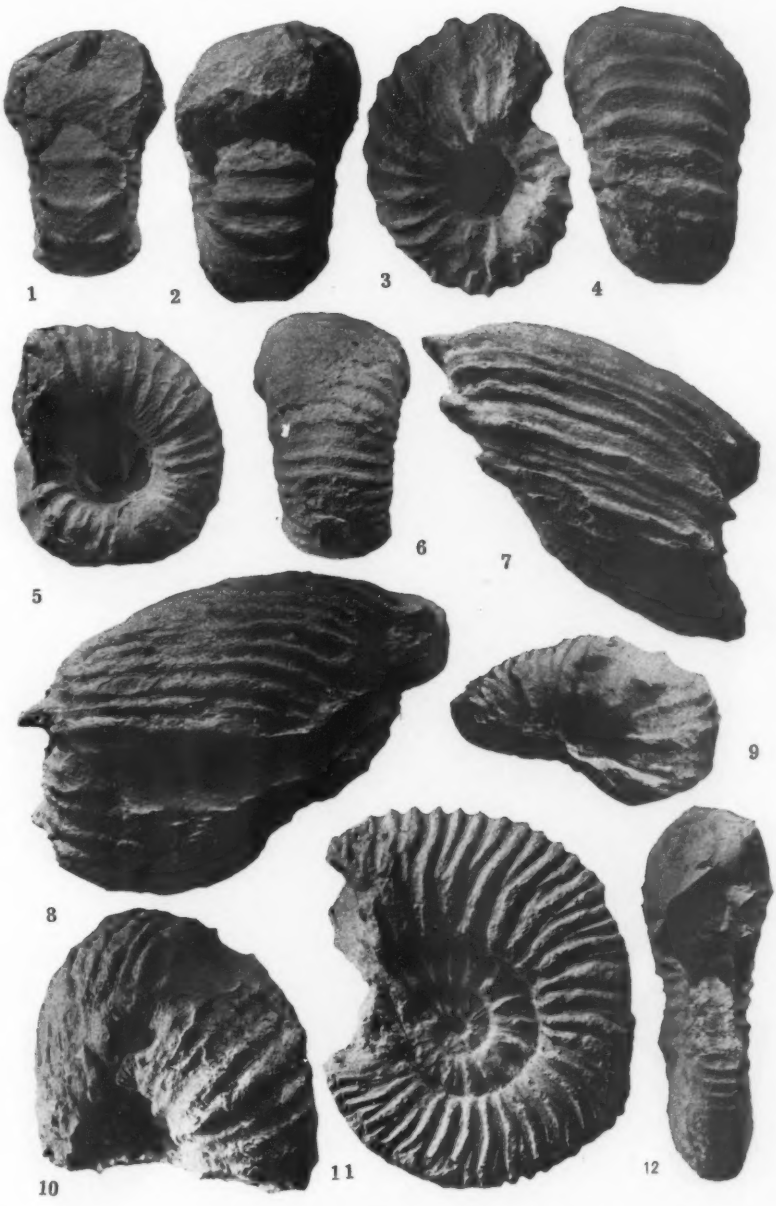

CHELONICERAS and *HYPACANTHOPLITES*

CHELONICERAS and *MEGATYLOCERAS*

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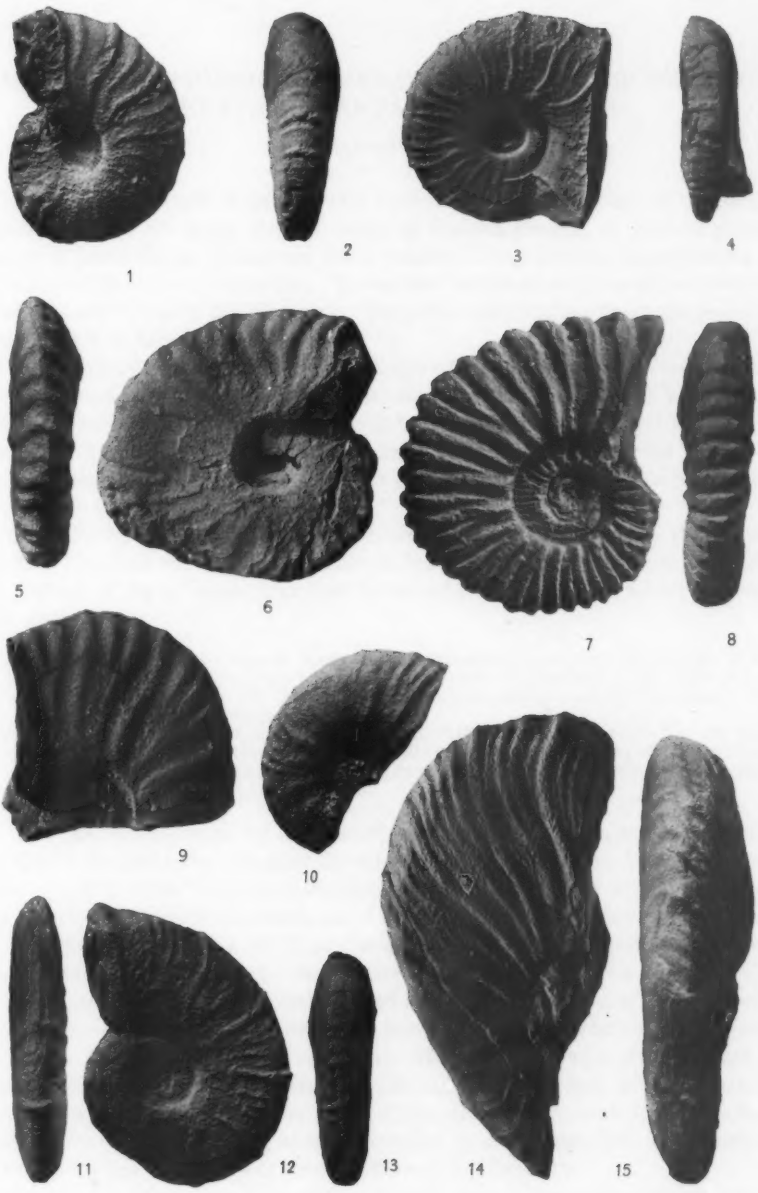

COLOMBICERAS, UHLIGELLA, and *PSEUDOHAPLOCERAS?*

BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
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JAMES EIGHTS' PIONEER OBSERVATION AND INTERPRETATION OF ERRATICS IN ANTARCTIC ICEBERGS

BY LAWRENCE MARTIN

One of the high points in initial world knowledge of glacial geology is the astute interpretation by the great English naturalist Charles Darwin, in 1839, of glacial erratics in South Indian Ocean and South Atlantic Ocean icebergs as indications of the nature of bedrock in Antarctica. It may now be shown that Darwin was anticipated by some 9 years in this discovery. His predecessor was the American geologist James Eights of Albany, N. Y.

The basis of Darwin's conclusion was a single rock in an iceberg observed by John M'Nab, second mate of the English schooner *Eliza Scott* in 61° S., 103° 40′ E., together with information supplied by Messrs. Enderby, Sorrell, Horsburgh, and Biscoe. It was a huge iceberg, as we know from a contemporary drawing, the visible portion of it rising some 300 feet above the sea. The glacial erratic was 12 feet in height and 5 to 6 feet in width.

Charles Enderby made the following statement about the finding of this glacial erratic. The place was a point in the South Indian Ocean poleward from Australia. The logbook of the schooner *Eliza Scott* furnished information from which Enderby drew up the record:

> "*March 13th.* [1839]—Light variable winds from the eastward; surrounded by icebergs: in lat. 61°, long. 103° 40′, passed within a ¼ of a mile of an iceberg about 300 feet high, with a block of rock attached to it, as represented in the following woodcut from a drawing made on the spot by Mr. John M'Nab [sic], 2nd mate of the schooner.
>
> "He describes the rock as a block of about 12 feet in height, and about one-third up the berg: it is unnecessary here to make any observation upon this very remarkable fact, as Mr. Charles Darwin has appended a note to these extracts, pointing out the value of such an evidence of the transporting power of ice . . ." (Enderby, 1839, p. 526).

"Having been informed by Mr. Enderby, that a block of rock, embedded in ice, had been seen during the voyage of the schooner *Eliza Scott* in the Antarctic Seas", Darwin wrote in 1839, "I procured through his means an interview with Mr. Macnab [sic], one of the mates of the vessel, and I learnt from him the following facts:—On the 13th March, when in lat. 61° S., and long. 103° 40′ E., a black spot was seen on a distant iceberg, which, when the vessel had run within a quarter of a mile of it, was clearly perceived to be an irregularly-shaped but angular fragment of dark-coloured rock. It was embedded in a perpendicular face of ice, at least 20 feet above the level of the sea. That part which was visible, Mr. Macnab estimated at about 12 feet in height, and from 5 to 6 in width; the remainder (and from the dark colour of the surrounding ice, probably the greater part) of the stone was concealed. He made a rough sketch of it at the time, as represented at p. 524 [page 526]. The iceberg which carried this fragment was between 250 and 300 feet high.

"Mr. Macnab informs me," Darwin continued, "that on one other occasion (about a week afterwards) he saw on the summit of a low, flat iceberg, a black mass, which he thinks, but will not positively assert, was a fragment of rock. . . .

"Every fact on the transportation of fragments of rock by ice is of importance, as throwing light on the problem of 'erratic boulders,' which has so long perplexed geologists; and the case first described possesses in some respects peculiar interest . . . I have stated, on the authority of Captain Biscoe, that, during his several cruises in the Antarctic Seas, he never once saw a piece of rock in the ice. An iceberg, however, with a considerable block lying on it, was met with to the E. of South Shetland, by Mr. Sorrell (the former boatswain of the *Beagle*), when in a sealing vessel. The case, therefore, here recorded is the second; but it is in many respects much the most remarkable one. Almost every voyager in the Southern Ocean has described the extraordinary number of icebergs, their vast dimensions, and the low latitudes to which they are drifted: Horsburgh has reported the case of several, which were seen by a ship in her passage from India, in lat. 35° 55′ S. If then but one iceberg in a thousand, or in ten thousand, transports its fragment, the bottom of the Antarctic Sea, and the shores of its islands, must already be scattered with masses of foreign rock,—the counterpart of the 'erratic boulders' of the northern hemisphere" (Darwin, 1839a, p. 529).

"M. Cordier," Darwin concluded in a footnote, "in his instructions (L'Institut, 1837, p. 283) for the voyage of the *Astrolabe* and *Zélée*, says, that the shores of South Shetland were found, by the naturalist of an American expedition in 1830, covered with great erratic boulders of granite, which were supposed to have been brought there by ice. It is highly desirable that this fact should be inquired into, if any opportunity should hereafter occur" (Darwin, 1839a, p. 529).

Although Darwin hurriedly overlooked it, P. L. A. Cordier said on the very page of *L'Institut* cited that the naturalist of the American expedition of 1830 was James Eights. "Les relations de l'expédition anglo-américaine [American, not Anglo-American] de découverte exécutée en 1830, nous ont fait connaître que les plages des Nouvelles-Shetland [sic] sont couvertes de grands blocs erratiques formés de granite et par conséquent d'une nature différente des autres roches du pays. M. James Eights, naturaliste de l'expédition, n'hésite pas à considérer ces blocs comme ayant été apportés par les glaces qui viennent annuellement s'echouer et se fondre sur les plages dont il s'agit et comme étant les indices de terres inconnues situées plus près du pôle que la terre de Trinité."

Cordier's statement may be translated as follows. "The accounts of the American discovery expedition, carried out in 1830," the French geologist wrote in 1837, "make known to us that the shores of the South Shetland Islands are covered with large erratic boulders made of granite and, consequently, of a different nature than the other rocks in the region. Mr. James Eights, the naturalist of the expedition, had not hesitated to consider these boulders to have been carried by the ice which comes annually, goes aground, on the shores which it disturbs, and to be indications of the rocks nearer the South Pole than Trinity Land [the Palmer Peninsula] (Cordier, 1837, p. 283).

Darwin again quoted in 1839 the Cordier statement about Eights. This was in one of the volumes on the voyages of the *Adventure* and *Beagle* where he said "I have not been able to find any account of this expedition" (1839b, p. 612–613).

Imaginative but generally faithful drawings of MacNab's glacial erratic in its iceberg have been published by Sir Charles Lyell (1867, p. 381) and by Sir Archibald Geikie (1883, p. 100). Their publications have had such wide circulation that the observation and interpretation was not only made famous but has become known to thousands of students of glacial geology. Eights' publications, on the other hand, have been almost forgotten. That they were sound, however, will be agreed by those who read the following quotations. They are based upon observations upon the

opposite side of Antarctica from the region where the English schooner *Eliza Scott* was sailing in 1839 when ice carrying a giant glacial erratic was encountered.

The time was February 1830, in the South Shetland Islands south of the Cape Horn of South America, and March and April 1830, west of the Palmer Peninsula of the Antarctic mainland and north of Ellsworth Land. Eights recorded cruising between 60° and 70° south latitude and between 54° and 101° west longitude. He was in the American brig *Seraph*, a sealing vessel commanded by Captain Benjamin Pendleton.

"A few rounded pieces of granite are occasionally to be seen lying about, brought unquestionably by the ice-bergs from their parent hills on some far more southerly land, as we saw no rocks of this nature in situ on these islands. In one instance I obtained a boulder nearly a foot in diameter from one of these floating hills", (Eights, 1833, p. 61).

Eights had previously shown that bedrock in the South Shetland Islands consisted principally of basalt, argillaceous conglomerate, and sandstone. Hence granite boulders were obviously erratic.

The logbook of the schooner *Penguin*, one of the consorts of the brig *Seraph*, has an interesting entry on February 6, 1830. After referring to the icebergs in the straits between two of the South Shetland Islands, the logbook says: "Landed on one [iceberg] & got a specimen of rocks which are not found at Shetlands". No one in the party could have told the master of the vessel that the boulder from the iceberg was erratic, no one except Eights.

"The vast masses of snow and ice,"[Eights also wrote,] "that lie piled over the uneven superficies of the land, and the numerous icebergs that drift through the Southern ocean, and are every where strewed along its surface, are, in a peculiar manner, adapted to create feelings of awe and admiration. . . .

"Embraced within these drifting icebergs, rocky fragments, varying greatly in size, are not unusually to be seen, sometimes rounded into the boulder form, but for the most part angular, and so arranged as to present a dark striped, or partially stratified appearance, strikingly visible from the contrast of their darker hues, with those of the lighter tints of the ice in which they are inclasped. The origin of these last is extremely obvious, and admit of a simple explanation. In many places, isolated masses of the rock that constitute the land, are observed to penetrate and protrude far above the general level of the surrounding snows; portions of these are almost continually falling, from the expansive power of the congealing water among their fissures: these fragments are thrown upon the indurated surface of the snows, and are then slidden to some considerable distance from whence they were derived; upon these the falling snows soon accumulate to a sufficient depth to retain them in their places, until they become firmly embraced within the mass. When portions of these glaciers are detached, and tumble into the sea, icebergs bearing rocky fragments are then produced. These fragments . . . are frequently borne along, and deposited in regions far remote from the parent rock, from whence they were detached" (Eights, 1833, p. 64).

Such were some of the conclusions of Eights in the field of glacial geology while working in the South Shetland Islands. Now we must consider where he went and what he saw and how he interpreted his observations while sailing in the waters southwest of the South Shetlands, west of the Palmer Peninsula, south of Peter I Island, and in other parts of the ocean northward from the Ellsworth Land of the Antarctic mainland.

This was what Eights alluded to in 1833 (p. 62, 68) as "our cruize to the southwest above the 60° of south latitude" and also as "our course from the south Shetlands to the southwest, until we reached the 101° of west longitude". The American geologist's conclusions depend, as will be observed, not only on glacial geology but also on

observations in the fields of meteorology, oceanography, and marine zoology. "Not a day occurred that snow did not fall or ice make on our decks, and during the time we spent in exploring, between the latitudes of 60 and 70 degrees south, and 54 and 101 west longitude, which was more than two months, we found the current often setting with considerable velocity, from the southwest to the northeast. The prevailing winds were also most commonly from the southwest and northwest. . . ." (Eights, 1834, p. 168).

"The existence of a southern continent within the Antarctic Circle is, I conceive, a matter of doubt and uncertainty; but that there are extensive groups or chains of islands yet unknown, I think we have many indications to prove, and were I to express an opinion, I would say, that our course from the south Shetlands to the south west, until we reached the 101st degree of west longitude, was at no great distance along the northern shores of one of these chains" (Eights, 1834, p. 168).

[Eights then proceeded to give his bases for considering that there was land not far distant to the southward.] "The heavy clouds of mist which encircled us so often could arise from no other cause than that of the influence of large quantities of snow or ice on the temperature of the atmosphere; the hills of floating ice we encountered, could not form elsewhere than on the land. The drifting fuci we daily saw, grow only in the vicinity of rocky shores, and the penguins and terns, which were almost at all times about us, from my observation of their habits, I am satisfied, never leave the land at any great distance. During our cruize to the southwest above the 60° of south latitude, we found the current setting continually at a considerable rate towards the northeast, bearing the plants and ice along in its course, some of the latter embracing fragments of a rock, the existence of which, we could discover no where on the islands we visited. When the westerly winds drew well toward the south, we were most generally enveloped in banks of fog, so dense that it was with difficulty we could distinguish objects at the distance of the vessel's length. When Palmer's land [now called the Palmer Peninsula] becomes properly explored, together with the known islands, situated between the longitude of Cape Horn and that of Good Hope, I think they will prove to be the north eastern termination of an extensive chain, passing near where Capt. Cook's progress was arrested by the firm fields of ice, in latitude 71° 10′ s. and west longitude about 105°. Had that skilful navigator succeeded in penetrating this mass of ice, he would unquestionably in a short time have made the land upon which it was formed" (Eights, 1833, p. 62, 68).

The extensive chain of islands whose existence Eights forecast was, of course, not an archipelago at all but a portion of the Antarctic mainland. It was the northern coast of what we now call Ellsworth Land. Explorations by the Belgian de Gerlache, the Australian-American Wilkins, and by Admiral Richard E. Byrd in surface ships and in airplanes have demonstrated that there are no islands except Charcot Island between the course of the brig *Seraph*, in which Eights was travelling and from which he made his observations in 1830, and Antarctica itself. Hence it is perfectly safe to say that the Albany scientist forecast the existence of an important portion of the Antarctic coast in 1830.

In 1943 the United States Board on Geographical Names paid the following well-deserved tribute to Eights, adopting the place-name Eights Peninsula for

"the peninsula between Bellingshausen Sea and Amundsen Sea, terminating in latitude approximately 71° 20′ S., longitude approximately 98° W., named after James Eights, scientist on the brig *Seraph* of Stonington, Connecticut, Benjamin Pendleton, Master. Eights, while sailing probably within 85 miles of this peninsula in 1830, first deduced the existence of at least 450 miles of adjacent Antarctic lands".

It should not be forgotten that Mount Darwin, a peak 6890 feet in height in Tierra del Fuego, as well as the 6200-foot Darwin Mountains near the coast of Victoria Land, the Mt. Darwin on the west side of Beardmore Glacier, and the Darwin Islet east of Joinville Island, all three in Antarctica, were named for Charles Robert Darwin.

Darwin, as should be recognized, was well acquainted with the transportation of erratics by ice. While working in Patagonia and Tierra del Fuego and other parts of southern South America, during the voyage of the *Adventure* and *Beagle*, he identified

erratic blocks, not *in situ*, 67 miles from the nearest mountain. He concluded that they owed their positions to "transport by ice while the country was under water". He referred to one 47-foot boulder which was 90 miles distant from the parent rock and said its transportation had not been violent. In 1839, in the Addenda to his Journal and Remarks of 1832–1836, Darwin also said "we know that icebergs of the present day, in both hemispheres, occasionally transport fragments of rock" (Darwin, 1839b, p. 267–268, 288).

It is unfortunate that Darwin was unfamiliar with the publications of Eights. When the former wrote his *Note on a rock seen on an iceberg in 61° South Latitude*, in 1839, the articles on the American geologist's Antarctic observations and interpretations of the year 1830 had already been published in the *Transactions of the Albany Institute*, in the *Mercantile Advertiser and Advocate* of New York, in *Niles' Weekly Register* of Baltimore, Maryland, and in the *Boston Journal of Natural History*. They had also been commented upon in France. Not all of these American publications, however, may have been easily available in England in 1839.

John M. Clarke (1916, p. 189–202) of the State Museum at Albany, N.Y., and W. T. Calman (1947, p. 171–184) of the Linnean Society of London have paid high tributes to Eights as a scientist, and James Hall, one of the great masters of American geology, put himself on record as believing James Eights to have been "the possessor of the keenest scientific mind that Albany had ever known" (letter from John M. Clarke to Leon J. Cole, March 20, 1905).

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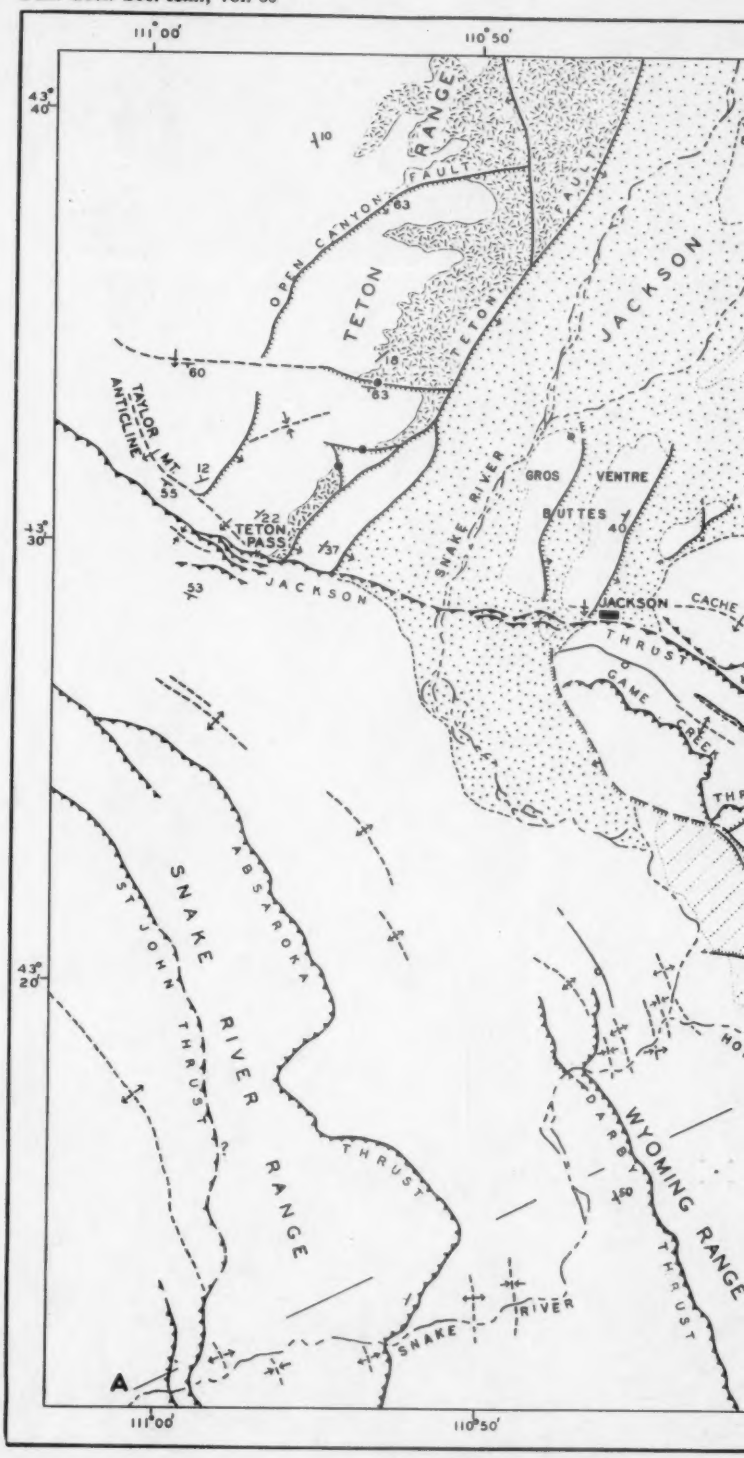

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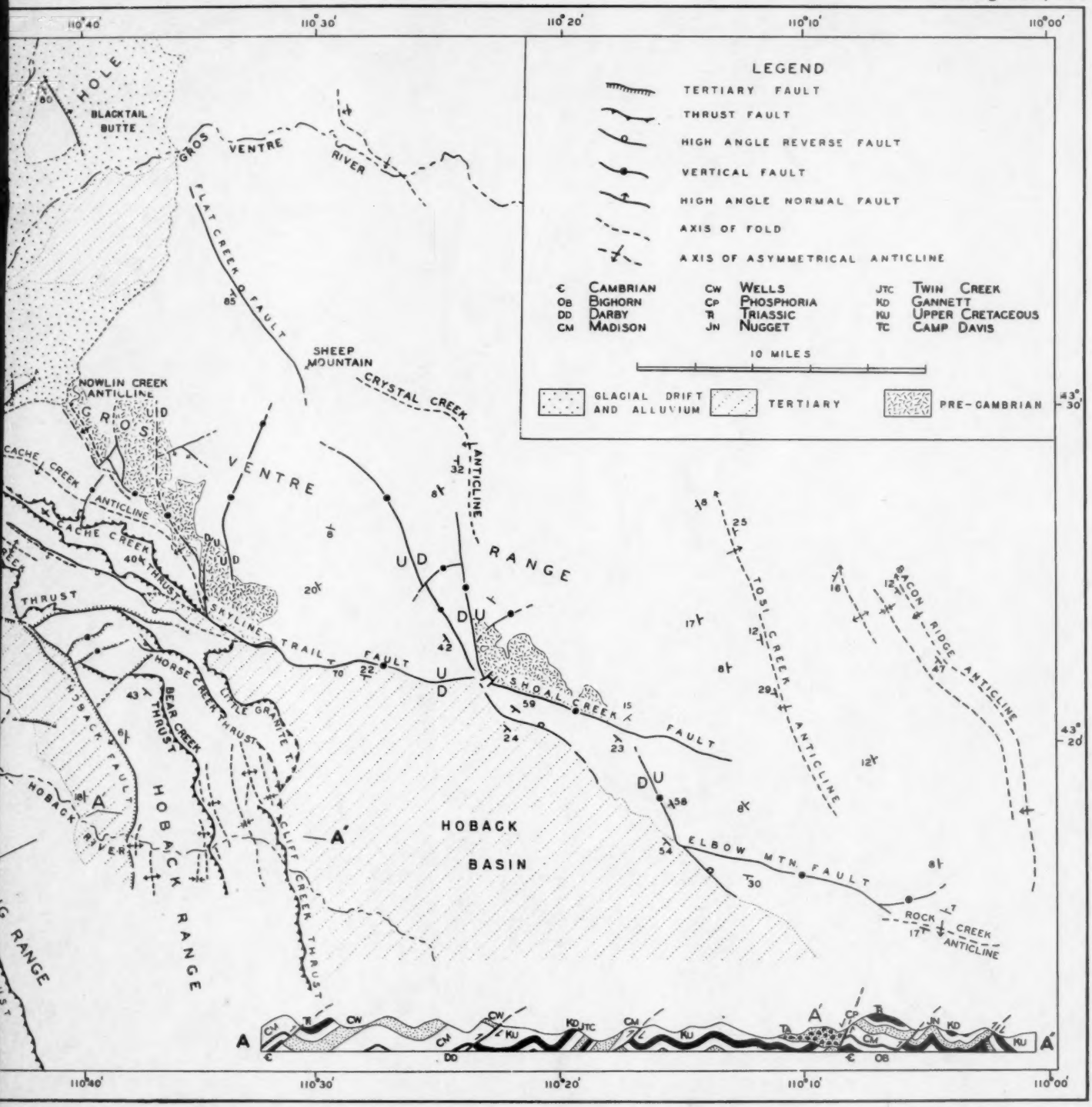

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STRUCTURAL TRENDS IN CENTRAL WESTERN WYOMING

BY LELAND HORBERG, VINCENT NELSON, AND VICTOR CHURCH

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ABSTRACT

The area extending southeastward from the south end of Teton Basin, Idaho, to the northern part of Green River Basin, Wyoming, exhibits two types of Laramide structure modified by Tertiary high-angle faults. Included within the area are parts of the Teton, Gros Ventre, Hoback, and Snake River ranges.

Structure in the Teton and Gros Ventre ranges consists of broad, asymmetrical anticlines, a major northeast-dipping thrust fault, and three large fault blocks. Structures in the Hoback and Snake River ranges include close folds of Appalachian type and low-angle, southwest-dipping thrust faults. Initial Teton-Gros Ventre structures probably were formed during an early phase of Laramide orogeny and, as buttresses, controlled the trend and character of the later Hoback-Snake River structures. Laramide movements appear to have begun in the Late Cretaceous and continued at least into late Eocene time. Tertiary faults of Basin-Range type and with north-south trends transect older structures and are responsible for the east scarp of the Teton Range, small fault blocks in Jackson Hole, and the western boundary structure of the northern Hoback Range.

Regional stratigraphic relations had an important effect on both the trend and type of Laramide deformation, but this influence cannot be recognized in the Basin-Range faulting.

INTRODUCTION

LOCATION

The report concerns an area about 20 miles wide and 60 miles long which extends southeastward from Teton Basin, Idaho, to the valley of Green River at the east end of the Gros Ventre Range (Fig. 1). The region lies within the Middle Rocky Mountain physiographic province and includes portions of the Teton Range, Snake River Range, Jackson Hole, Hoback Range, and the greater part of the Gros Ventre Range. Elevations range from 6,000 to over 11,000 feet and much of the area is mountainous and inaccessible by roads.

GENERAL STATEMENT

Although the broader structural features of central western Wyoming have long been known, recent studies have revealed distinctive structural types and trends

previously unrecognized. Many of these structural features were described in earlier publications on the Teton Range, northern Snake River Range, northern Hoback Range, and western and central Gros Ventre Range (Horberg, 1938; Nelson, 1942; Nelson and Church, 1943). In order to obtain a clearer understanding of regional structural relations, geologic mapping was extended in the present study to include additional areas in the eastern part of the Gros Ventre Range and northern part of the Hoback Range, and a number of critical localities previously studied were

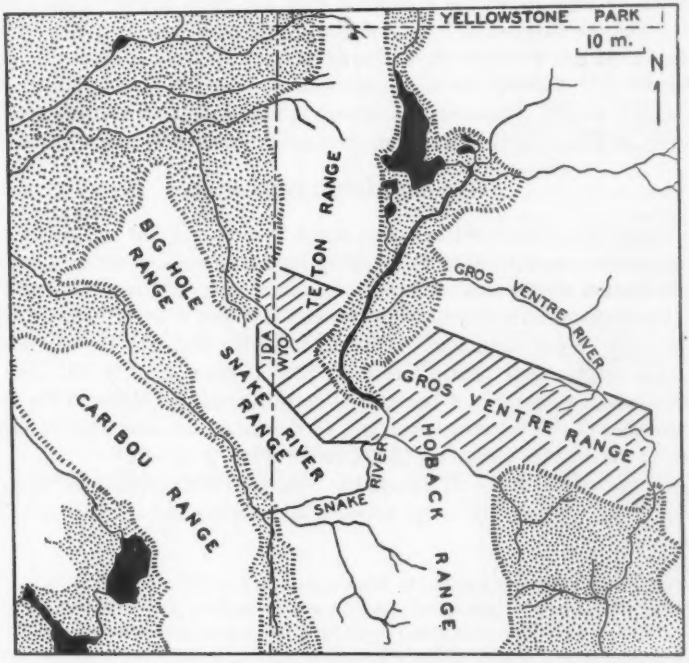


FIGURE 1.—*Index map of central western Wyoming*

Area covered by present study shown by diagonal shading.

re-examined. The purpose of the present paper is to describe the major structural features from a regional viewpoint and to discuss their physical and chronologic development.

PREVIOUS WORK

The earliest geological investigations in the area were made by Orestes St. John (1879, p. 411–456, 474–508; 1883, p. 202–227) who clearly outlined some of the major structures in the Teton and Gros Ventre ranges. Later studies by Schultz (1914; 1918) revealed close folding and overthrusting in the Hoback and Snake River ranges, and Blackwelder (1911, p. 452–81; 1915, p. 97–117, 193–217, 307–340) pointed out

the importance of Tertiary faulting in the region. More recently, Eardley (1944) and students at the University of Michigan field camp have done extensive geologic mapping in adjoining areas, especially to the south.

FIELD WORK AND ACKNOWLEDGMENTS

Field work was carried on during the summers of 1933–1940. Completion of investigations in the northern part of the Hoback Range and the eastern portion of the Gros Ventre Range during the summer of 1940 was made possible through a grant from the Penrose Bequest by the Geological Society of America. The writers are indebted to the late Professor R. T. Chamberlin, F. M. Fryxell, R. P. Sharp, A. H. Sutton, and A. J. Eardley for suggestions and criticism; to Donald Hiller, Thomas Roberts, and Robert Crawford who served as field assistants in 1940; and to the University of Michigan Geology Camp and local residents for many kindnesses.

STRATIGRAPHIC SUMMARY

The region lies between better known areas to the southwest and northeast, and the stratigraphic units adopted in mapping form a composite section (Table 1) in which formation names from different areas have been utilized. In general, the section corresponds more closely to central and northern Wyoming than to the geosynclinal area to the southwest. Only the following divisions shown on Table 1 are local in origin: Gros Ventre formation (Blackwelder, 1918, p. 417–26); Death Canyon limestone member of the Gros Ventre formation (Miller, 1936, p. 119); Leigh member of the Bighorn formation, Darby formation, and Darwin sandstone member of the Amsden formation (Blackwelder, 1918, p. 417–26).

No attempt will be made to discuss the numerous stratigraphic problems of the area, but brief notes on the usage adopted in mapping and regional relations are given below:

(1) The Cambrian formations defined by Blackwelder (1918, p. 417) are distinctive lithologic units and, although their time-stratigraphic unity may be open to question (Deiss, 1938, p. 1103; Dorf and Lochman, 1940, p. 542), they are retained as the most logical mappable divisions.

(2) The Tensleep and Amsden formations, mapped together as the Wells-formation, are distinct stratigraphic units and could have been mapped separately. The Darwin sandstone member of the Amsden is present throughout the area.

(3) The Chugwater red beds include units which are lithologically similar to the Red Peak, Alcova, Crow Mountain, and Popo Agie formations of the Chugwater group of central Wyoming (Branson and Branson, 1941, p. 133–136). Southwestward, they are believed to grade laterally into the Woodside and Thaynes formations of southeastern Idaho (Newell and Kummel, 1942, p. 937–996) (Fig. 2).

(4) The Nugget sandstone traced eastward can be identified as the Wypo formation of the Chugwater group (Branson and Branson, 1941, p. 133–136); at the east end of the Gros Ventre Range, the Gypsum Spring formation (Love, 1939, p. 41–48) appears between the Nugget and Twin Creek (Sundance) formations.

(5) The Twin Creek and Stump formations in the western part of the area occupy the same position in the section as the Sundance formation farther east (Fig. 2).

(6) The Morrison formation of central Wyoming traced westward thickens greatly and can be recognized as part of the Gannett group of southeastern Idaho (Mansfield, 1927, p. 49).

(7) The beds mapped as "Eocene-Paleocene" (Pl. 2) east of the Hoback Range have been differ-

TABLE 1.—*Stratigraphic section in the Teton, Snake River, Hoback and Gros Ventre ranges*

Age	Formation	Thickness (Feet)	Lithology
Recent	Alluvium		Post-glacial stream deposits, alluvial fans, landslides and related deposits.
Pleistocene	Pinedale drift Bull Lake drift Buffalo drift		Glacial till, outwash, and loess.
	~~Unconformity~~~		
Lowermost Pliocene or Upper Miocene	Camp Davis conglomerate	5000±	Conglomerate and agglomerate of local derivation with thin fresh-water limestone. Fossil horse tooth found in limestone member.
	~~? Unconformity~~~		
Lower or Middle Miocene	Basic breccia		Andesitic flows, breccias, and associated intrusive porphyry. Vertebrate fossils found in tuffs at north end of Jackson Hole.
	~~Unconformity~~~		
Middle Miocene	Pass Peak conglomerate	1500+	Coarse quartzite conglomerate with interbedded sandstone. Eocene plants and fresh-water mollusks found south of the area in Hoback basin.
	~~Unconformity~~~		
Lower Eocene (?)—Paleocene	Hoback formation	5000±	Interbedded gray sandstone and shale with fresh-water limestone beds and some conglomerate. Fossil invertebrates occur in the limestone. Fossil carnivore jaw found in Hoback basin.
	~~? Unconformity~~~		
Upper Cretaceous	Frontier formation	3000+	Gray and buff shale and interbedded sandstone with coal beds. Plant and invertebrate fossils.
	Aspen formation	600–1000	Sandy gray shale and massive sandstones with thick beds of speckled greenish-gray vitrified rhyolite tuff (porcellanite).
	Bear River formation	250–1000	Black carbonaceous shale with thin fossiliferous limestones overlain by "salt and pepper" sandstones. Marine fossils.
	~~Unconformity~~~		

TABLE 1.—*Continued*

Age	Formation	Thickness (Feet)	Lithology
Lower Cretaceous—Upper Jurassic(?)	Gannett (Morrison) formation	370–950	Red, purple, and gray shales; gray sandstones with some conglomerate; and gray limestones. Fresh water invertebrate fossils occur in the limestones; "gastroliths" and rare bone fragments occur in the shales.
	~~? Unconformity~~~		
Upper Jurassic	Stump sandstone Preuss sandstone Twin Creek limestone Sundance formation (east Gros Ventre Range)	700–1000	Gray-green, thin-bedded, calcareous sandstone; weathers brown. Marine fossils. Red sandstone and shale in Snake River Range. Dense gray limestone and buff to light-gray shaley limestone which weathers into small splinters and chips. Abundant marine fossils.
Middle Jurassic	Gypsum Spring formation	50	Red shale with interbedded limestone and gypsum in eastern Gros Ventre Range.
	~~Unconformity~~~		
Middle or Lower Jurassic	Nugget sandstone	300–350	Salmon-colored to buff, fine-grained, massive sandstone.
	~~Unconformity~~~		
Lower Triassic	Thaynes limestone Woodside shale Chugwater formation	1000–2700	Red shale, siltstone, and sandstone with interbedded dense gray limestone; abundant ripplemarks and mud-cracks. Marine fossils in Thaynes limestone.
	~~? Unconformity~~~		
	Dinwoody formation	200–760	Brownish-gray to dull olive-green, calcareous platey siltstone with and limestone. Marine fossils.
Permian	Phosphoria formation	200–350	Gray to black shales, brown sandstones, and dolomites with limestone, and phosphate rock. Chert and cherty limestone beds at top represent the Rex chert member. Fossil fish and marine invertebrates.

TABLE 1.—*Continued*

Age	Formation		Thickness (Feet)	Lithology
Pennsylvanian	Wells formation	Tensleep sandstone	325–1140	Buff, white and pink, massive sandstone, weathers brown; cross-bedded and evenly bedded. Rare fusulinids.
		Amsden formation	300–700	Chocolate to red shale and gray cherty dolomite. A basal sandstone, 50 to 100 feet thick, represents the Darwin sandstone member. Marine fossils.
	~~Unconformity~~~			
Mississippian	Madison limestone		800–1400	Blue-gray, dense limestone; shaley and thin-bedded to massive. Chert nodules are common in the upper part. Abundant marine fossils. Upper massive cherty beds may be equivalent to the Brazer limestone of southeastern Idaho.
	~~Unconformity~~~			
Devonian	Darby formation		300–570	Variegated, calcareous shale and siltstone underlain by dark-gray, fetid dolomites, Marine fossils sparingly present.
	~~Unconformity~~~			
Ordovician	Bighorn dolomite		350–400	Light-gray, massive dolomite with rough pitted surfaces. Fossils are rare. An important cliff-maker. About 50 feet of dense thinner-bedded dolomite at the top forms the Leigh member.
	~~Unconformity~~~			
Upper Cambrian	Gallatin limestone		150–250	Blue-gray, mottled limestone with green silty partings. Fossils rare.
Middle Cambrian	Gros Ventre shale		550–750	Upper (Park) shale—olive-gray shale with oolitic limestone and intra - formation breccia. About 200 feet thick. Fossil algae locally abundant; other fossils rare. Death Canyon limestone—dark-gray, thin-bedded limestone with yellow-brown mottled areas. 150 to 450 feet thick. Fossils rare.

TABLE 1.—*Concluded*

Age	Formation	Thickness (Feet)	Lithology
			Lower (Wolsey) shale — gray-green to dark-gray shale which grades downward into green and brown, sandy, micaceous beds. Abundant fossils at certain horizons.
	Flathead sandstone	175–260	White, maroon, and brown quartzitic sandstone. Hematitic, micaceous sandstone and shale at top. Local basal conglomerate. Fossils rare.
	~~Unconformity~~~		
Pre-Cambrian			Gneiss and schist intruded by granites and pegmatites. Younger basic dikes may be present.

entiated by Eardley (1944) into the Hoback and Pass Peak formations. On the basis of fresh-water fossils, the Hoback formation was assigned a lower Eocene age and the Pass Peak formation, which overlies it unconformably, a middle Eocene age. However, an early carnivore jaw found in 1947 is probably late Paleocene in age (A. J. Eardley, personal communication, 1948) and indicates that at least the lower half of the Hoback formation is Paleocene. The deposits are found in both overlap and fault relations with the older formations in the ranges, but the relative extent of these relations is uncertain.

(8) The Pass Peak conglomerates (Pl. 2) are included by Eardley (1944) in the Pass Peak formation and are thus considered to be middle Eocene. Blackwelder (1915, p. 204) had correlated these deposits with the Pinyon conglomerate of the Yellowstone region. Recent studies (Love, 1947), however, indicate that the Pinyon conglomerate may be Paleocene and thus considerably older.

At the type locality near Pass Peak the conglomerate is composed of pebbles averaging about 2½ inches in diameter and has a friable sandstone matrix. Over 75 per cent of the pebbles are of foliated quartzite and the remainder consist largely of chert, vein quartz, schist, gneiss, and quartzitic sandstone. Interfingering beds of sandstone become more conspicuous south of the area where the maximum thickness of the formation may reach 5000 feet (Eardley, 1944). The conglomerates west of Granite Creek consist largely of locally derived materials and include fresh-water limestones. Metaquartzite cobbles appear to be absent. The age of these deposits is uncertain. They may be Pass Peak, as shown in Plate 2 and Eardley's map (1944), or they may represent marginal facies of the Hoback formation.

(9) The Tertiary volcanics in the south Teton Range and Gros Ventre buttes include andesitic flows, breccias and porphyries which resemble the late basic breccias of the Yellowstone Region. Vertebrate fossils found in associated tuffaceous sediments near the north end of Jackson Hole (Pilgrim Creek, Grand Teton quadrangle) indicate lower or middle Miocene age (Colbert, 1943, p. 298–305; Schultz and Falkenbach, 1947, p. 228–32).

(10) The Camp Davis formation, which flanks the Hoback Range on the west, is composed of conglomerate and fanglomerate with thin fresh-water limestones. It differs from the Pass Peak conglomerate in being composed largely of Mesozoic and Paleozoic sedimentary rocks of local derivation. An upper Miocene or lower Pliocene age is evidenced by a fossil horse tooth (Eardley, 1942, p. 1800).

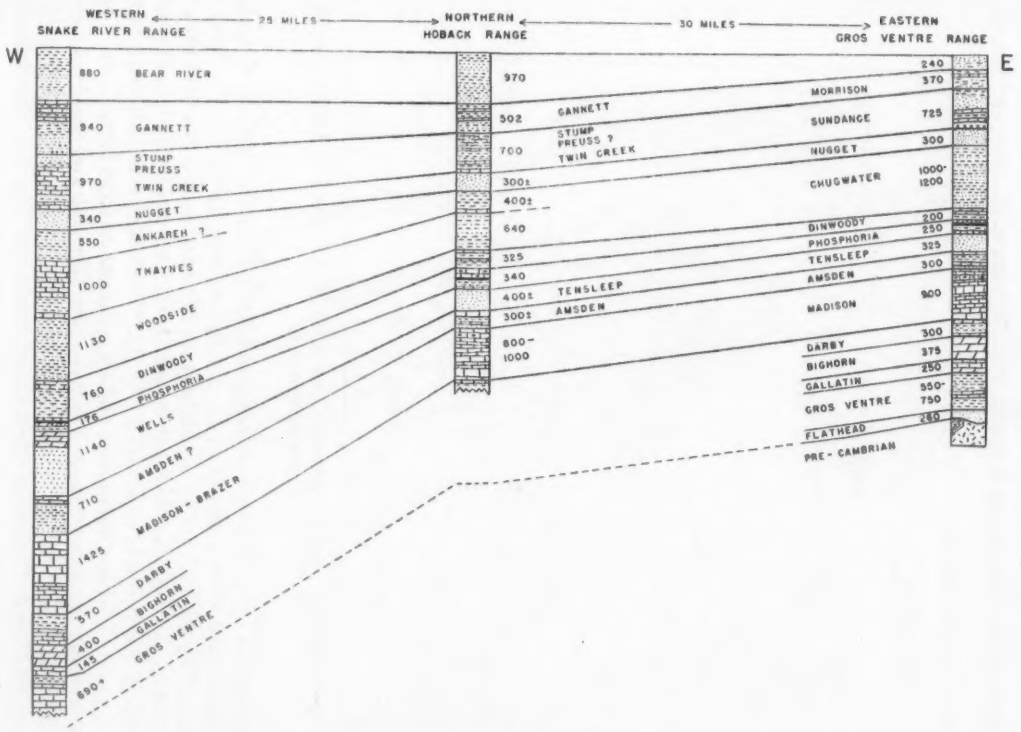


FIGURE 2.—*Columnar sections*

Showing thickening of sediments to southwest. Compiled from Blackwelder (1918), Dobrovolny (1940), Gardne (1944), Newell and Kummel (1942), Richmond (1945), and measurements by the writers.

As first pointed out by Blackwelder (1911, p. 467), there are important facies changes and a thickening of essentially the entire stratigraphic column in going from east to west in the area. This lateral gradation has been substantiated by later stratigraphic studies (Newell and Kummel, 1942; Wanless *et. al.*, 1946) and is strik-

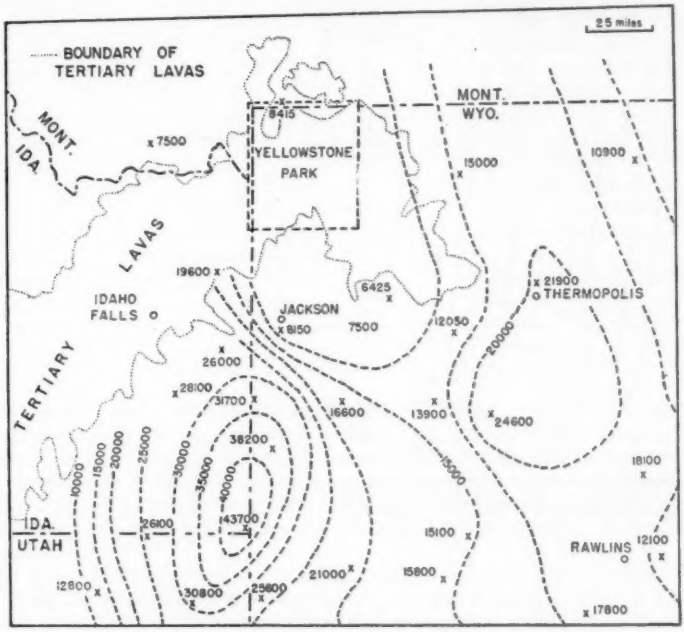


FIGURE 3.—*Isopach map showing thickness of Paleozoic and Mesozoic systems in western Wyoming and adjacent areas*

ingly revealed by comparing sections in the eastern Gros Ventre, northern Hoback, and western Snake River ranges (Fig. 2). From a regional standpoint, the changes are explained by the fact that the area is near the northeast margin of a deep trough in the Cordilleran geosyncline and that the section thickens rapidly to the southwest as the axis of the trough is approached (Fig. 3). Thickening is accomplished both by the appearance of new formations and by expansion of local formations. The changes are most pronounced in the Pennsylvanian (Tensleep and Amsden formations), Triassic (Dinwoody, Woodside, and Thaynes), Jurassic-Lower Cretaceous (Gannett), and Upper Cretaceous (Bear River) formations (Fig. 2). The profound influence exerted by sedimentary facies on structural types and trends is an outstanding geological feature in the region.

REGIONAL RELATIONS

Two zones of Laramide deformation representing distinctive trends and structural types can be recognized in the Middle Rockies. The western zone occupies the

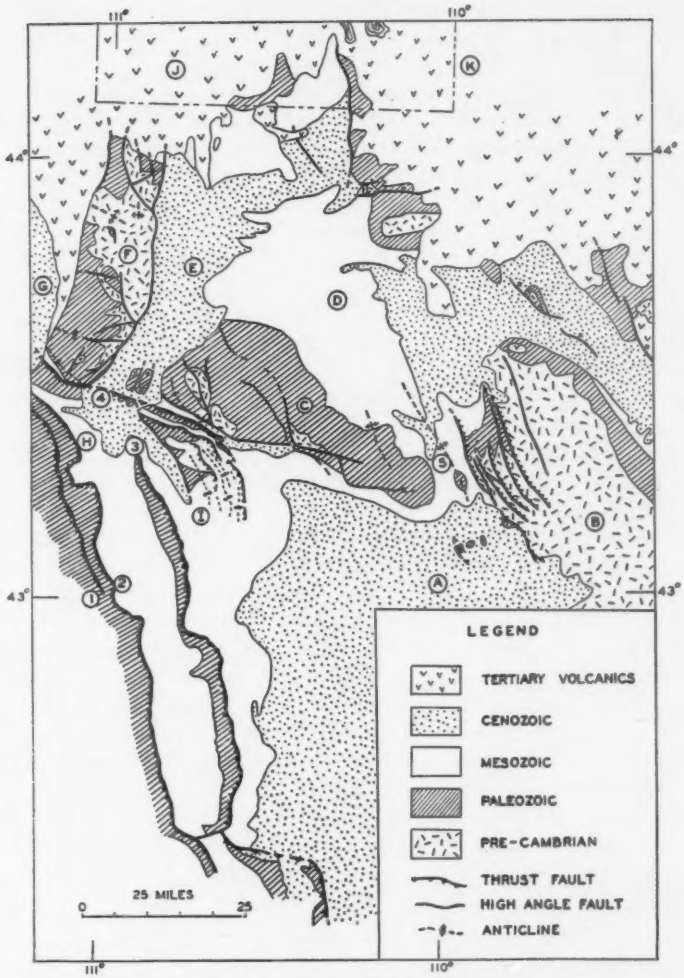


FIGURE 4.—*Structure map of western Wyoming and adjacent areas.*

A—Green River Basin; B—Wind River Range; C—Gros Ventre Range; D—Gros Ventre Basin; E—Jackson Hole; F—Teton Range; G—Teton Basin; H—Snake River Range; I—Hoback Range; J—Yellowstone Plateau; K—Absaroka Range; 1—St. John fault; 2—Absaroka fault; 3—Darby fault; 4—Jackson fault; 5—Bacon Ridge anticline and Kendall dome.

axial part of the Rocky Mountain geosyncline (Figs. 3, 4) and includes the mountains extending southward from the Teton Range along the Wyoming-Idaho boundary into northeastern Utah. The eastern zone occupying the platform or foreland area,[1]

[1] The term "platform" is used in a stratigraphic sense for the area of thinner sediments adjoining a geosynclinal wedge of thicker equivalent beds; the term "foreland" is used in a structural sense for the region in front of a series of overthrust sheets.

east of the geosyncline is represented by the outer ranges of the Middle Rockies such as the Beartooth, Pryor, Big Horn, Owl Creek, Wind River, Washakie, and Gros Ventre ranges.

The structures of the foreland are broad, northwest-trending folds which commonly have crystalline rocks exposed in their central portions. They are characterized by structural asymmetry which is reversed within certain zones (Chamberlin, 1940), by marginal thrust faults, and locally by block movements along high-angle faults. Individual ranges are separated by broad basin areas containing deep fills of alluvial material (Fig. 1). In central western Wyoming these structures are typified by the Gros Ventre Range and related structures which continue west into the Teton Range (Pl. 1). Adjoining basins (Fig. 4) containing Tertiary sediments are represented by the Green River Basin, Jackson Hole, and parts of the Gros Ventre Basin north of the Gros Ventre Range (St. John, 1883, p. 219–227).

The structures of the geosyncline and its east margin have north-south trends and are characterized by linear, closely compressed folds of Applachian type accompanied by low-angle faults of great horizontal displacement. Movements along the thrust faults were to the northeast in contrast to movements along major faults in the adjoining foreland (Gros Ventre and Wind River ranges) which were to the southwest. Individual ranges are not separated by Tertiary basins and crystalline rocks are nowhere exposed along the axes of uplift. Within the area under consideration, typical geosynclinal structures are found in the Hoback and Snake River ranges.

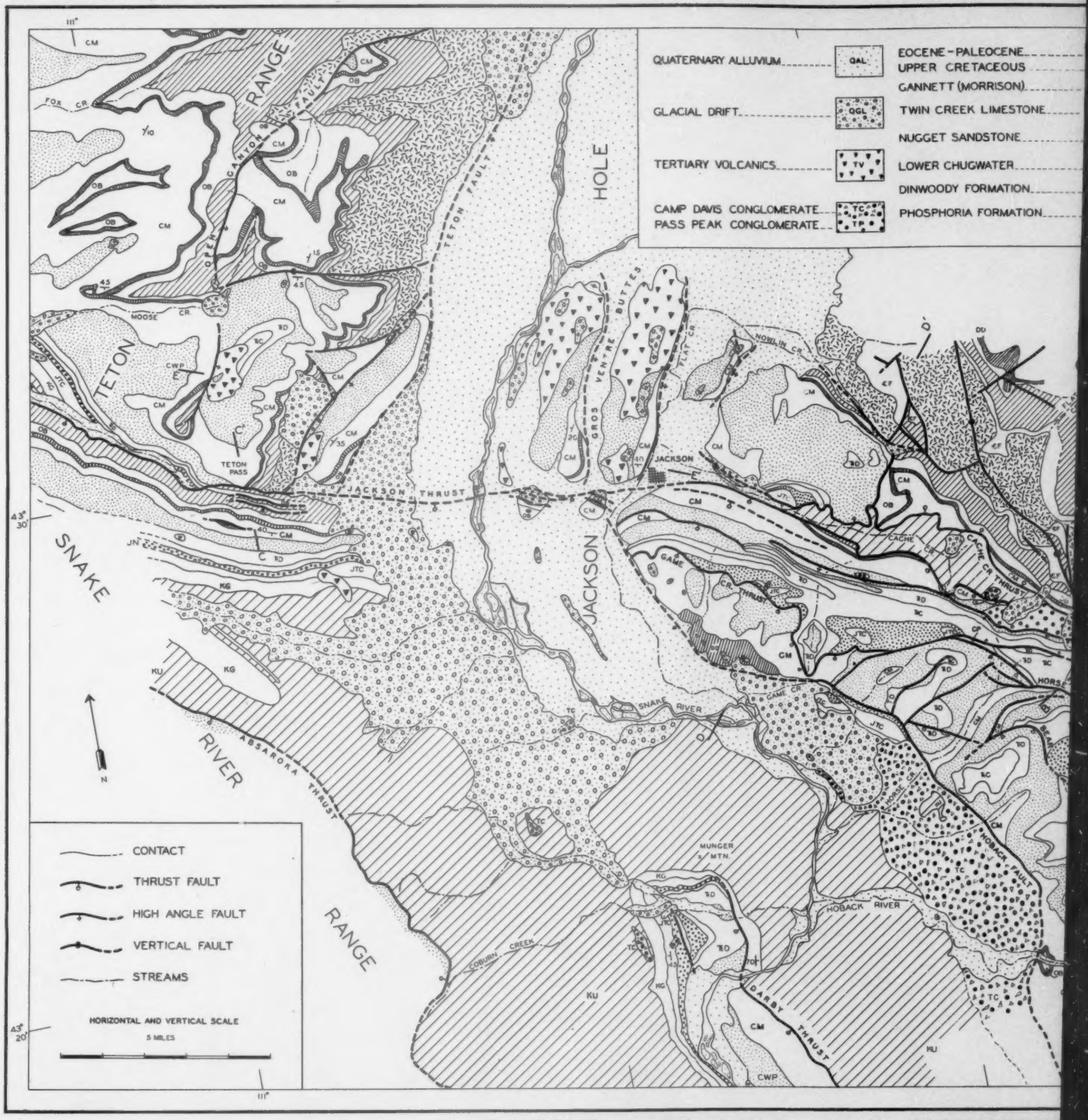
Superimposed upon the pattern of Laramide folds and faults are a series of high-angle faults of Tertiary age. These transect the older structures along north-south lines and show no apparent relation to foreland and geosyncline. This faulting is of Basin-Range type and is responsible for the impressive east scarp of the Teton Range, the small fault blocks rising as buttes from the floor of Jackson Hole, and the west boundary fault of the northern Hoback Range.

Volcanism centering around the Yellowstone Park region was active throughout the Tertiary and is recorded locally by volcanic materials extending southward into the Teton Range and Jackson Hole. The eruptives are of early Tertiary age and antedate the major movements along the high-angle faults of Basin-Range type.

FORELAND STRUCTURES

GROS VENTRE RANGE

General description.—The Gros Ventre Range is similar in many respects to the Wind River Range which adjoins it on the east (Fig. 4). Both are broad, asymmetrical anticlines with steep and locally faulted southwest limbs. Crystalline rocks are exposed in the cores of both ranges but are much more extensive in the Wind River Range. The asymmetrical Gros Ventre uplift has a broad gently-dipping northeast backslope and an abrupt southwest front. The southwest front is bordered by major faults throughout almost its entire length and is broken into three large fault blocks (Pl. 2, cross-sections A-A′, B-B′). Maximum displacement occurred along the southwest margin where the pre-Cambrian marks the points of greatest uplift (Pl. 2). The western end of the present range is transected by Tertiary faults (Pl. 3, fig. 1), but older structures continue for at least 20 miles beyond, across Jackson Hole and



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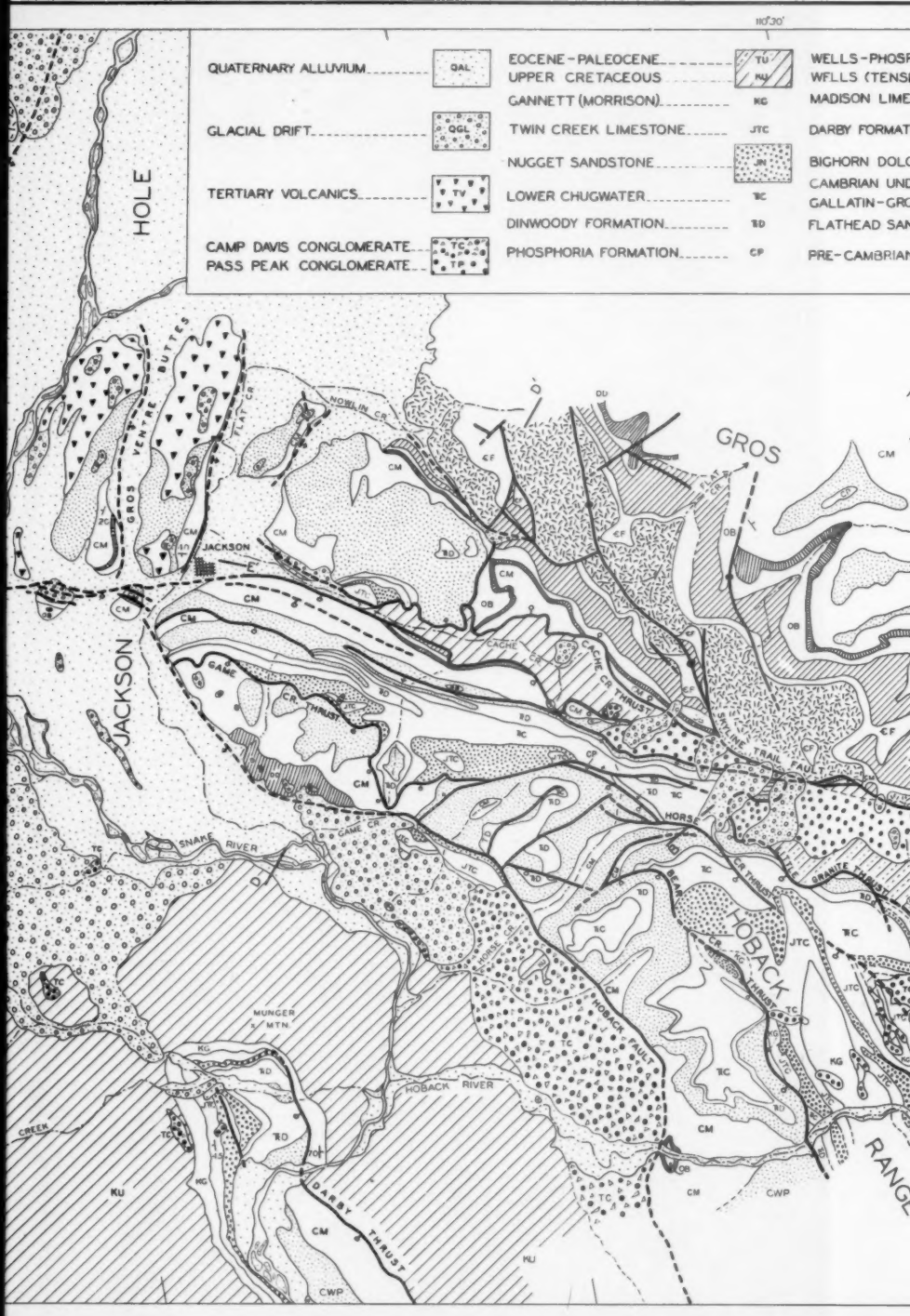

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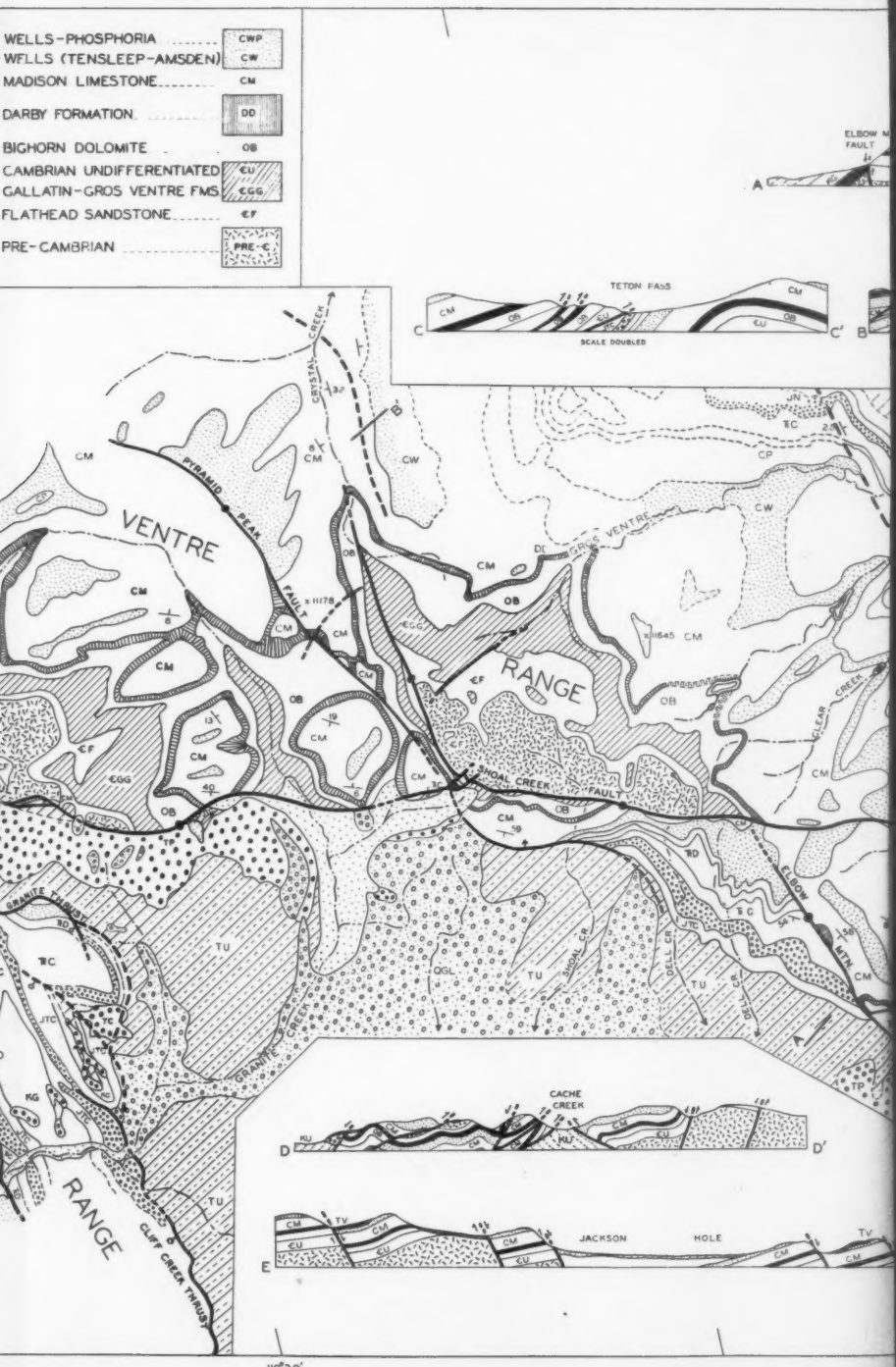

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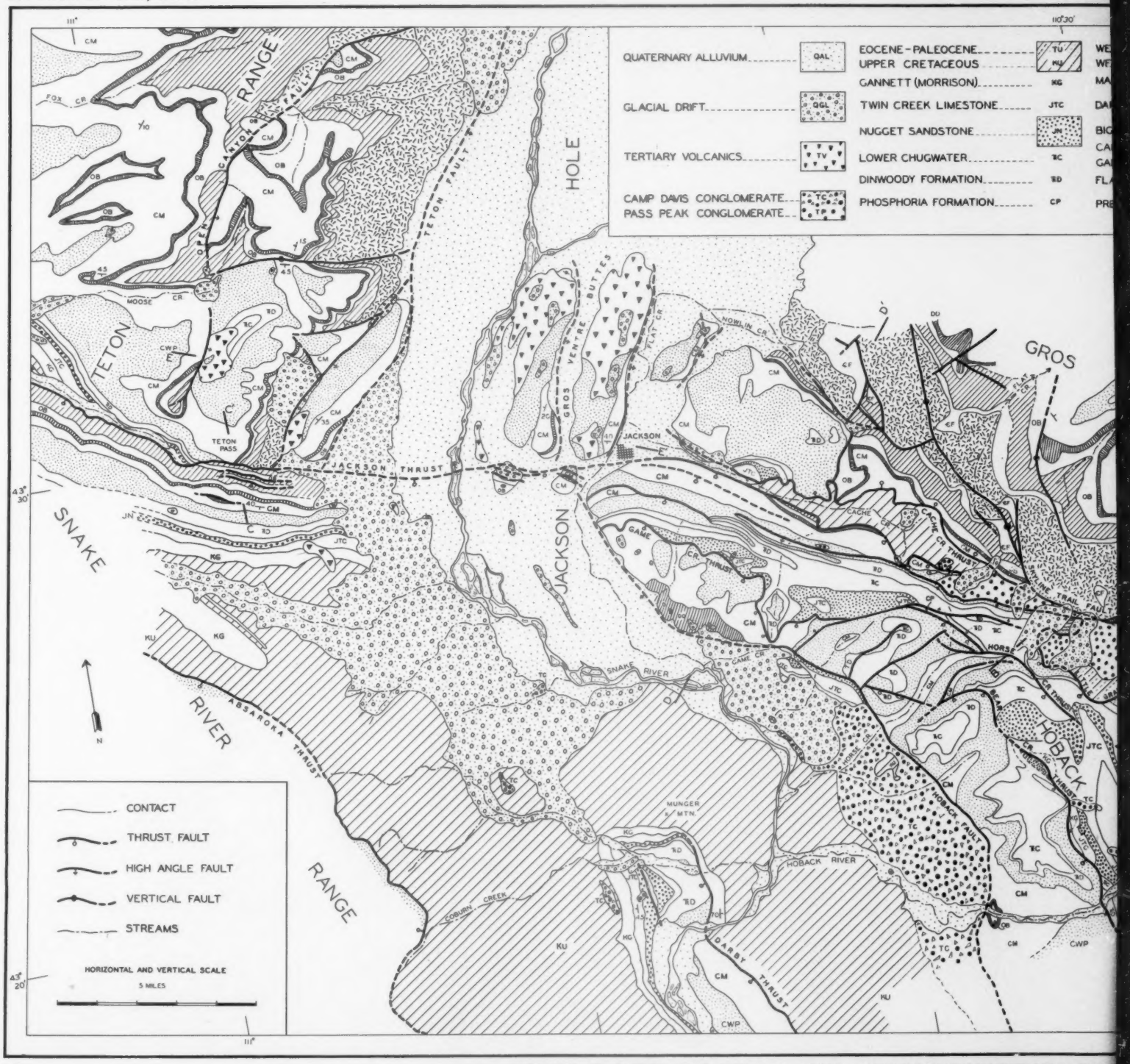

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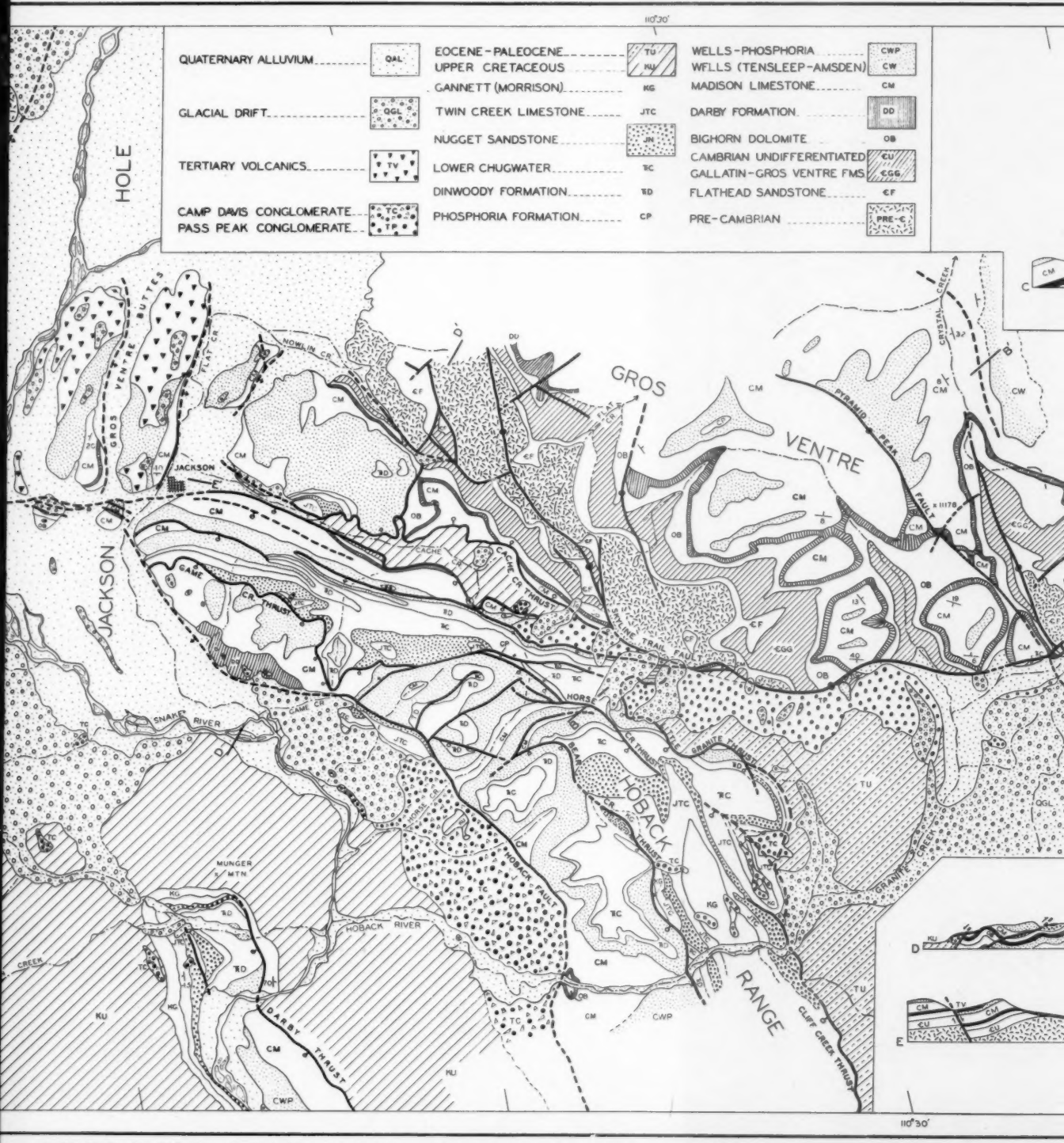

GEOLOGIC MAP AND STRUCTURE SECTIONS OF CENTRAL

RAL WESTERN WYOMING

into the Teton fault block where they pass below Tertiary volcanics. Gros Ventre deformation outlined the adjoining margins of the Green River basin on the south and the Gros Ventre basin on the north, and probably also is reflected in the structure of Teton Basin west of the present Teton Range.

Folds along the southwest front of the Range.—Although the entire backslope of the range may be considered the northeast limb of a major anticline, the steeper southwest limb of the fold is apparent only at the extremities of the range where it is preserved as the Cache Creek anticline on the west and the Rock Creek anticline on the east (Pl. 1). Elsewhere it has been obliterated by faulting.

Cache Creek Anticline: The Cache Creek anticline borders the north side of the valley of Cache Creek for 10 miles east from Jackson (Pls. 1,2), (Nelson, 1942, p. 15–18). It is locally overturned to the southwest and is broken by the northeast-dipping Cache Creek thrust fault (Pl. 3, fig. 2). Dips on the southwest range from vertical to 50°N. where overturning has been strong. Although transected by Tertiary faulting near Jackson, the westward continuation of what is probably the same fold is seen at the south end of East Gros Ventre Butte and in the south Teton Range as the Taylor Mountain anticline (Horberg, 1938, p. 33) (Pl. 1).

Rock Creek Anticline: The Rock Creek anticline is significant in marking the eastward termination of the major line of displacement along the south front of the range (Pl. 1). It is asymmetrical toward the south and its strike is parallel to the range. The fold dies out to the east as the north-south trending folds between the Gros Ventre Range and Wind River Range are approached; to the west it passes into the Elbow Mountain fault (Pl. 1).

Folds on the backslope of the Range.—At least four subordinate folds are superimposed on the gently-dipping northeast backslope of the range: the Bacon Ridge, Tosi Creek, Crystal Creek, and Nowlin Creek anticlines (Pl. 1).

Bacon Ridge Anticline: The Bacon Ridge anticline lies along the northeast margin of the range and has an average strike of about N. 30° W. Steeply-dipping Chugwater and Nugget beds on the southwest limb of the fold form the hogback ridge for which the structure is named (Pl. 2, cross-section A-A′). The northeast limb has been eroded to a lower level and is largely concealed by glacial drift. Maximum uplift and compression occurs midway along the ridge where dips of 50°SW. were measured. The amount of displacement and steepness of dip decrease rapidly to the north and beyond the area mapped the structure is overlapped by Tertiary sediments. The fold can be traced southeast across Green River where it assumes a N.-S. strike and terminates near the mouth of Lime Creek (Pl. 2).

Paralleling Bacon Ridge on the west is a minor north-plunging anticline beyond which the beds rise gradually westward to the crest of the Tosi Creek anticline.

Tosi Creek Anticline: The Tosi Creek anticline lies about 5 miles southwest of the Bacon Ridge anticline and closely parallels it with a strike of N. 20° W. It is also asymmetrical with maximum dips of about 30° on the steep southwest limb (Pl. 2, cross-section A-A′). The fold is well exposed along Tosi Creek which transects its axis and along which erosion has produced a window of Madison limestone (Pl. 2). Southward from Tosi Creek, the fold gradually flattens so that within 3

miles it is indiscernible as a significant structure. There is also a decrease in displacement northward as far as Clear Creek. North of Clear Creek, however, there apparently is a reversal of asymmetry so that the steep limb of the fold is on the northeast rather than the southwest. The reversal in form is accompanied by a steepening of dip from 12° on Clear Creek to about 25° on Gros Ventre River. The fold was not mapped beyond the ridge north of the river, but the strike of Cretaceous hogbacks seen from a distance indicate that it continues northward for at least 3 miles.

CRYSTAL CREEK ANTICLINE: The Crystal Creek anticline in the central part of the range is an asymmetrical fold with a steep southwest limb, but unlike the linear folds previously described the trend of the axis forms an almost right-angle bend (Pl. 1). To the south, displacement is taken up by the north arm of the Shoal Creek fault and to the west the fold either ends or turns abruptly north just east of Sheep Mountain. It does not appear to be continuous with the Flat Creek fault (Pl. 1) which extends northwestward from Sheep Mountain and represents the faulted southwest limb of a similar asymmetrical anticline.

NOWLIN CREEK ANTICLINE: The Nowlin Creek anticline (Pl. 1.) at the west end of the range is a large asymmetrical fold with dips of about 40° on the steep southwest limb. Vertical uplift is greater than in the folds previously described and pre-Cambrian rocks are exposed along its crest. To the southeast, the fold merges with the Cache Creek anticline and is broken by faults; to the northwest it passes below the alluvium and glacial deposits of Jackson Hole.

Fault blocks.—Along the south margin of the Gros Ventre Range, the steep limb of the primary arch is broken by three large fault blocks outlined by the Skyline Trail, Shoal Creek, and Elbow Mountain faults (Pl. 2). Each block is bounded on the west and south by a continuous vertical fault with maximum displacement at the southwest corner of the block. Northward and eastward the amount of displacement progressively decreases until the faults end. Pre-Cambrian rocks are exposed in the two westernmost blocks (Skyline Trail and Shoal Creek) and from east to west there is a progressive increase in displacement with maximum uplift along the Skyline Trail fault. Stratigraphic displacement at the southwest apex of the Skyline Trail block cannot be less than 6000 feet nor more than 11,000 feet; that of the Shoal Creek fault is 2600–3000 feet; and that of the Elbow Mountain fault is about 2500 feet. The blocks are similar in many respects to the asymmetrical uplifts in the Pryor Mountains of Montana (Blackstone, 1940, p. 590–618) and other areas adjoining the Big Horn basin.

SKYLINE TRAIL BLOCK: The Skyline Trail fault, which outlines the block, is a high-angle fracture which extends for almost 10 miles along the south front of the range before turning north at its western end (Nelson and Church, 1943, p. 153) (Pl. 2). After turning north the fault ends within about 2 miles. At its eastern end it is cut by the Shoal Creek fault. Along the front of the range, pre-Cambrian and Paleozoic rocks on the upthrow block are faulted against Mesozoic formations, which in turn are overlapped by the Pass Peak conglomerate (?) (Pl. 2). On the ridge west of Granite Creek (Pl. 2) the Pass Peak conglomerate (?) has been tilted

FIGURE 1. JACKSON HOLE, GROS VENTRE, AND HOBACK RANGES
Viewed from Teton Pass. The valley of Cache Creek, left center, lies between the foreland structures of the Gros Ventre Range on left (north) and geosynclinal trends of the Hoback Range on right (south). The small buttes, center, are Tertiary fault blocks preserving remnants of the Jackson thrust sheet. (National Park Service photo).

FIGURE 2. JACKSON AND CACHE CREEK THRUST SHEETS
Looking north across the divide at the head of Cache Creek. The ridge of vertical Madison limestone in the foreground marks the edge of the Jackson thrust; the valley beyond is underlain by Cretaceous shales; the scarp to rear is composed of Paleozoic strata of the Cache Creek thrust sheet.

FORELAND AND GEOSYNCLINAL TRENDS

FIGURE 1. SKYLINE TRAIL FAULT WEST OF GRANITE CREEK, GROS VENTRE RANGE
Viewed from south. Pass Peak (?) conglomerate (Tc) in foreground is faulted against the pre-Cambrian forming a scarp.

FIGURE 2. FAULTED SEGMENT SOUTH OF THE SHOAL CREEK FAULT, GROS VENTRE RANGE
Viewed from the east. The lowland on the left is underlain by Tertiary beds; the faulted block of steeply dipping beds is made up of Paleozoic sediments; the peaks in the background are composed of pre-Cambrian crystalline rocks.

TRAPDOOR FAULTING

toward the mountain front and was clearly involved in late movements along the fault (Pl. 4, fig. 1). Near the fault the beds on the upthrow side are bent over into steep southwest dips or are vertical; those on the downthrow have similar dips or are locally overturned.

Closely associated with the block is a high-angle fault which branches northwestward from the north arm of the main fault. Upthrow and downthrow relations on this fault are the reverse of those along the Skyline Trail fault and displacement increases to the north rather than the south. This pivotal movement in relation to the major fault is of particular interest, since almost identical relations are shown by a similar fault branching in the same direction from the Shoal Creek block.

Shoal Creek Block: The Shoal Creek fault, which bounds this block, can be traced for nearly 9 miles along the south side of the block and for about 3 miles on the west side (Pl. 2). Maximum displacement occurred about 2½ miles east of the southwest corner of the block and is estimated as 2600 to 3000 feet (pre-Cambrian to Tensleep). In contrast to the Skyline Trail fault, displacement is between pre-Cambrian and Paleozoic rocks or within the Paleozoic and does not extend to the Mesozoic beds. It differs also from the Skyline Trail fault in its position within, rather than at the front of the range. At this point the range front is outlined by a fault to the south along which Paleozoic and younger beds are faulted against the Tertiary sediments in Hoback basin. On the ridge between Granite Creek and Shoal Creek (Pl. 2), the Madison limestone on the upthrow side of the border fault dips 60°–70° to the south and forms a prominent peak called the "Flying Buttress" (Nelson and Church, 1943, p. 156) (Pl. 4, fig. 2). The attitude of the fault surface is uncertain, but its arcuate trace suggests a northward dip.

From the southwest corner of the Shoal Creek block, a subsidiary fault with reversed displacement extends northwest across the center of the range. The displacement is slight near the Shoal Creek fault but increases to the northwest reaching 1000–1200 feet. Its relations are thus strikingly similar to those of the branch fault on the west side of the Skyline Trail block described above.

Elbow Mountain Block: In the Elbow Mountain block, fault-block structure is again brought to the front of the range to form a prominent fault-line scarp. The block is bounded on the west and south by the Elbow Mountain fault (Pl. 2). Maximum uplift occurred at the southwest corner of the block where there is a stratigraphic displacement of about 2500 feet.

The displacement along the fault diminishes rpaidly northward and dies out in the Wells formation on the south (downthrow) side of the Shoal Creek block. To the east, the displacement decreases less rapidly but eventually dies out in the Wells formation in the vicinity of Rock Creek. Several brecciated and slickensided surfaces along the trace of the fault at the head of Big Twin Creek (Pl. 2) are essentially vertical, but at one place a 65° dip to the south was measured.

The Elbow Mountain block has no branch fault to the west, but a fault similar to that south of the Shoal Creek fault extends southeast from the southwest corner of the block. This fault has a stratigraphic displacement of less than 1000 feet and dies out rapidly to the southeast. South of Jack Creek (Pl. 2) the fault trace suggests a relatively low angle compared with the Elbow Mountain fault.

Cache Creek thrust.—The Cache Creek thrust (Pl. 2) represents a break along the southwest front of the Gros Ventre anticline at the west end of the range. The fault plane dips northeast and its irregular trace indicates a relatively low angle. Beds along the front of the thrust sheet range from Ordovician (Bighorn) to Jurassic (Nugget) and those exposed along the floor of the Cache Creek valley below the thrust plane are Upper Cretaceous[2]. The maximum stratigraphic displacement is over 5000 feet. At about its midpoint the thrust sheet is broken by a high-angle transverse fault along which displacement diminishes to the north. Eastward the thrust fault is intersected by the high-angle fault bounding the Skyline Trail block and to the west it is lost beneath the cover of alluvium at the mouth of Cache Creek.

In a radically different interpretation by Eardley (1944), the Cache Creek thrust, instead of terminating against the Skyline Trail fault, is continued eastward as the east limb of the Skyline Trail fault, and still farther eastward as the two branch faults lying south of the east limbs of the Shoal Creek and Elbow-Mountain faults (Pl. 2). A continuous thrust fault is thus shown along the entire south margin of the range from Jackson Hole eastward at least as far as Jack Creek. The writers' interpretation, whereby the Cache Creek thrust terminates against the Skyline Trail fault, is based on the traces of the faults which indicate an abrupt change from low-angle faulting to high-angle block faulting at the apex of the Skyline Trail block. The critical area in which the faults join is covered with glacial drift. If the thrust fault continues eastward, the thrust relations must have been largely obscured by uplift of the Skyline Trail block. Between the Shoal Creek and Elbow Mountain blocks, the extent of fault and overlap relations between the "Eocene-Paleocene" (Pl. 2) and older rocks is uncertain, but a continuous thrust fault appears possible. No evidence of thrust faulting was observed along Jack Creek or to the east. Although a definite decision would be unwarranted, the writers feel that their interpretation is most consistent with the evidence now available.

TETON RANGE AND JACKSON HOLE

Laramide folds are preserved in fault blocks rising from the floor of Jackson Hole and in the Teton Range itself. Sharply folded Paleozoic formations transected by Tertiary faults occur at the south end of East Gros Ventre Butte, the north extremity of West Gros Ventre Butte, and in Blacktail Butte (Pl. 1). Within the Teton Range, the asymmetric Taylor Mountain anticline at the south end of the range (Pl. 1) and two broad salients of pre-Cambrian rocks farther north (Fig. 4) probably represent westward extensions of Gros Ventre structure trends.

GEOSYNCLINAL STRUCTURES

GENERAL DESCRIPTION

The structures in the Snake River and Hoback ranges are more complex than those in the Gros Ventre and Teton ranges and the rocks involved are largely Mesozoic

[2] Fossils obtained from beds exposed along the road at the mouth of Cache Creek valley were identified by J. B. Reeside, 1944, as forms typical of the Frontier formation. The coal bearing beds exposed up the valley near the old "Jackson Mine" (Jackson quadrangle map) are similar lithologically, but may be younger.

rather than Paleozoic. They consist of a series of parallel folds and major thrust faults which trend slightly west of north in marked divergence to the Gros Ventre trends (Pl. 1). There is, however, a pronounced change in their strike as they approach the southern margin of the Teton and Gros Ventre ranges. The outstanding structural feature of the ranges is a series of roughly parallel thrust faults of large displacement which from west to east include: the St. John, Absaroka, Darby, and Jackson thrusts, together with a complex of secondary thrust faults in the Hoback Range (Pl. 1).

The Snake River Range structures continue northwest as the Big Hole Range and south as the Salt River and Wyoming ranges. The Hoback Range terminates to the north against the Gros Ventre Range, but it continues south beyond the area mapped for at least 50 miles (Fig. 4). Two intermontane basins, Jackson Hole and Teton Basin, are outlined in part by the Laramide structures of these ranges, although Tertiary faulting and warping has probably been the major factor in their origin.

SNAKE RIVER RANGE

The structure of the Snake River Range is dominated by four of the major thrust faults noted above. Topographically the faults are reflected by fault-line scarps developed on the resistent Paleozoic formations of each thrust sheet (cross-section A-A′, Pl. 1). The range has not been mapped in detail, but local studies in the western part (Gardner, 1944, Pl. 1) indicate greater complexity than is shown by the generalized cross-section.

The oldest rocks in the range are exposed on the west flank where Cambrian beds occur along the St. John thrust fault (Kirkham, 1924, p. 33–34) where it crosses Snake River. The central crest of the range follows the Absaroka thrust which is probably the largest of the overthrusts both in horizontal and stratigraphic displacement. Where this fault crosses Snake River, Madison limestone (Mississippian) has been thrust over the Aspen formation (Upper Cretaceous) along a fault plane which cannot be dipping more than 30° W. The irregularities of the fault trace indicate a horizontal displacement of not less than 2 miles. East of the Absaroka thrust the Darby thrust fault forms the main crest of the Wyoming Range south of Snake River with the Madison limestone thrust over the Bear River formation (Upper Cretaceous) in most places. Where the fault crosses Snake River, displacement has decreased so that the Tensleep sandstone (Pennsylvanian) is faulted against the Twin Creek limestone (Jurassic). Less than 3 miles north of the river the fault ends in a north plunging anticline (Pl. 2).

Associated with the major thrusts are numerous secondary faults and parallel folds. These have not been mapped in detail except locally, but are known to be present throughout the range.

One of the most notable structural features of the area is the change in strike and abrupt termination of Snake River Range structures where they abut the south end of the Teton fault block at Teton Pass (Pl. 2). The outer margin of deformation is here marked by the Jackson thrust along which Cambrian and Ordovician strata have been thrust northward across the eroded southwest limb of the Taylor Mountain anticline. West of Teton Pass (Pl. 2), the strike of the beds along the limb of

the fold diverge from the trace of the thrust, and progressively younger strata appear from beneath the thrust sheet. The fault relations are clearly revealed at Teton Pass where the Nuget and Twin Creek formations (Jurassic) are exposed below Cambrian limestone indicating a dip of less than 30° for the fault plane. South of the pass the thrust sheet is broken by three imbricate faults with higher dip and the lower Paleozoic formations are repeated three times before the crest of the main ridge to the south is reached. East of Teton Pass, remnants of the Jackson thrust sheet are preserved in two small fault blocks in Jackson Hole (South Gros Ventre Buttes), and in the Hoback Range the fault continues eastward as the outermost thrust in that range.

HOBACK RANGE

General relations.—Hoback Range consists of complex structures similar to those of the Snake River Range, but less uplift has taken place. The summit ridges for the most part are underlain by resistant units of the Mesozoic section instead of by Paleozoic formations (Pl. 2). On the north and east the range is outlined by a series of low-angle overthrusts; on the west the Laramide structures have been downfaulted along the northwest-trending Hoback fault (Pl. 2), which is a normal fault of Tertiary age. The internal structure of the range consists of parallel folds which become more closely compressed to the east and are cut by a number of low-angle thrust faults.

Thrusting from the southwest.—As in the Snake River Range, the structural trends of the Hoback Range are deflected to the west at the point of impingement against structures to the north—in this case the Gros Ventre Range. At no other point within the region are the two major structural types brought together more strikingly than along the valley of Cache Creek east of Jackson (Pl. 2). Here the north slope of the valley is made up of steeply dipping Paleozoic beds along the Cache Creek thrust, while the ridge on the south is held up by vertical strata of similar age on the Jackson thrust sheet (Pl. 2). The valley bottom is underlain by Upper Cretaceous beds and for a distance of 10 miles the two opposite-dipping thrusts are less than a quarter of a mile apart (Pl. 3, fig. 1).

Stratigraphic relations along the Jackson thrust southeast of Jackson reveal Cambrian to Pennsylvanian strata thrust northeastward over Upper Cretaceous beds. The average strike of the fault is N. 60° W. and the fault plane dips to the southwest at a moderately steep angle. Traced eastward the fault is cut off by a steep transverse fault. East of this fault, the thrust sheet is buried beneath Tertiary (Pass Peak (?)) conglomerates on the downthrow block. Where an outer thrust is again brought to the surface 3 miles east, the stratigraphic relations are not the same and the angle of dip is much lower. It is uncertain whether this fault, called the Little Granite thrust (Pl. 2), is to be considered the continuation of the Jackson thrust. Although its marginal position would favor this conclusion, this is discounted by the fact that Tertiary movement occurred along the Little Granite thrust, but not along the Jackson, and by the lower angle of dip of Little Granite thrust.

The first thrust fault south of the Jackson thrust is the Game Creek thrust (Pl. 2) which can be traced from the east side of Jackson Hole southeastward for 7 miles.

FIGURE 1. GAME CREEK THRUST NEAR MOUTH OF GAME CREEK, HOBACK RANGE
Viewed from south. Madison limestone (Mm) is resting on Chugwater red beds (Tc). Steepening of dip of the fault plane is produced by drag along the Hoback fault.

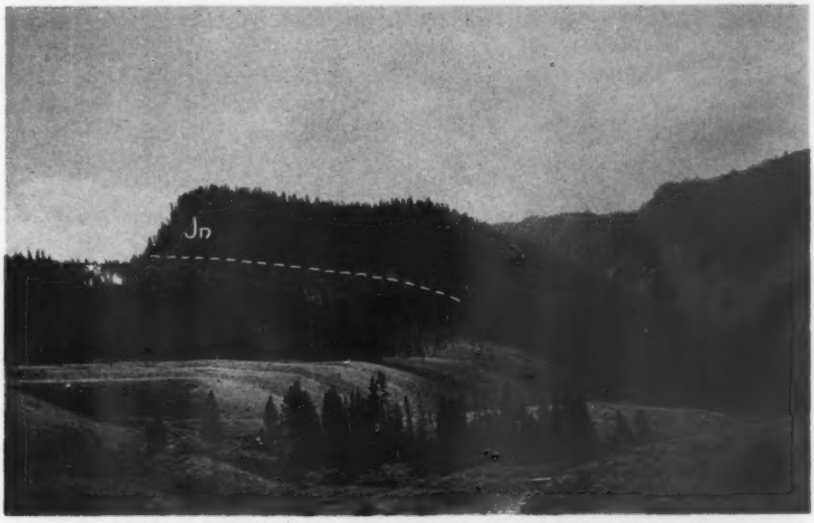

FIGURE 2. CLIFF CREEK THRUST NEAR THE MOUTH OF GRANITE CREEK, HOBACK RANGE
Viewed from northwest. Nugget sandstone (Jn) is faulted against the Hoback formation.

FIGURE 1. EAST GROS VENTRE BUTTE AND TETON RANGE FAULT BLOCKS
Looking north across Jackson Hole (Photo by Haines, Jackson, Wyoming).

FIGURE 2. EAST SCARP OF THE TETON RANGE FAULT BLOCK
The central peak is the Grand Teton (13,766 feet). Truncated and facetted spurs, hanging valleys, and an abrupt linear mountain front are evidences of faulting (National Park Service photo).

TERTIARY FAULTING

Along the front of the thrust, the fault plane is essentially horizontal and in the valley of Game Creek (Pl. 2) it is well exposed for a distance of 1½ miles before it dips suddenly to the southwest and passes below the surface (Pl. 5, fig. 1). This sudden change in dip appears to be due to drag along the Hoback fault which transects Laramide structures along the west margin of the range. There is no comparable overthrust in the Snake River Range to the west and the fault either ends below the Quaternary deposits in Jackson Hole or passes into one of the minor faults behind the Jackson thrust. To the southeast the thrust fault is transected and downfaulted by a high-angle fault with east-west trend, beyond which it may be represented by the Horse Creek thrust.

The Horse Creek thrust follows the main upper branch of Horse Creek for 2½ miles and, at the point of maximum displacement, Madison limestone (Mississippian) has been thrust over the Chugwater red beds (Triassic). Stratigraphic displacement along the fault diminishes to the west and, if it is a continuation of the Game Creek thrust, significant folding prior to faulting is implied. Similarly there is a decrease in stratigraphic displacement to the southeast and the fault either ends in the Nugget formation (Pl. 2) or, as shown by Eardley (1944), continues southeastward through complexly deformed Nugget and Twin Creek beds to Granite Creek.

The main crest of the range is bordered by the Bear Creek thrust (Pl. 2) which appears as a broad anticlinal structure thrust eastward over the west limb of a closely compressed syncline. Fault relations are well exposed along the canyon of Hoback River where Tensleep sandstone Pennsylvanian) can be seen resting on overturned Dinwoody and Chugwater (Triassic) beds. Maximum displacement occurs about 2 miles north where the Tensleep is faulted against the Gannett formation (Lower Cretaceous or Upper Jurassic). Northward, the fault swings west and is transected by a high-angle fault near the west front of the range. South of Hoback River it has been traced (Eardley, 1944) for about 10 miles where it joins the major thrust fault bordering the Hoback Range on the east.

Eastern boundary structure.—The eastern border of the Hoback Range is outlined by overthrusting along the Little Granite Creek thrust to the north and the Cliff Creek thrust to the south (Pl. 2). Along these faults, which probably are continuous, Triassic and Jurassic formations are thrust eastward over the Paleocene beds in Hoback Basin (Pl. 5, fig. 2). Within the area mapped, the beds east of the fault were mapped as the Evanston formation (Ft. Union) by Schultz (1914, Pl. 1), but more recent studies (Eardley, 1944) indicate that they represent the lower part of the Hoback formation (Paleocene). Near the north end of the Little Granite Creek thrust, conglomerates interpreted as a local facies of the Pass Peak conglomerate were overridden by the thrust sheet. Similar relations at the front of the range were mapped by Eardley (1944) near Lookout Peak about 20 miles south. The Little Granite Creek thrust is essentially horizontal at its northern end, but it appears to steepen to the south where its trace and that of the Cliff Creek thrust indicate a considerably higher angle. Two interpretations of the boundary relations along the east side of the range appear in the literature: (1) By Schultz (1914, p. 68–71 and Pl. 1), the contact was mapped and interpreted as an unconformity of more than 20,000 feet; (2) Blackwelder (1911, Fig. 53, p. 465) regarded the boundary relation

as due to normal faulting with the younger beds downfaulted on the east. More detailed studies by the writers and later by Eardley (1944) indicate thrust-fault relations along the boundary within the area and for 20 miles south.[3] The possibility of unconformable relations is negated by: (1) the absence of locally derived Nugget and Twin Creek material in the Tertiary beds, even where these occur at the base of Nugget cliffs 200 to 300 feet high; (2) clear evidence of faulting in the form of breccia, slickensided fragments, and drag phenomena. Thrust faulting rather than normal faulting is indicated by the irregular trace of the fault, by direction of drag, and by the thrust relations exposed where the fault crosses Cliff Creek $2\frac{1}{2}$ miles south of Hoback River. Here the Nugget sandstone has been overturned along the front of the thrust sheet in normal drag relations and Tertiary beds occur both immediately in front and below the ledges of Nugget.

Although the Tertiary beds east of the fault have been sharply folded in places, the Cliff Creek thrust may properly be considered the eastern border of Hoback Range deformation.

Folds.—Although Schultz's reconnaissance map (1914, Pl. 1) shows the northern Hoback Range as a series of parallel folds and entirely without faults, folding was much less important than thrust faulting. In the western half of the range, competent Paleozoic beds are folded into a broad anticlinal uplift modified by lesser folds; in the eastern half of the range east of the Bear Creek fault, less competent Mesozoic formations are closely compressed into narrow folds. Maximum uplift occurred near the west border of the range where the Bighorn dolomite (Ordovician) is exposed along Hoback River in the core of a small, steep, north-plunging anticline (Pl. 2). The folded structures and major faults are strikingly displayed by almost continuous cross-sectional exposures along the canyon of Hoback River, the route followed by U. S. Highway 187.

Associated with the larger folds are numerous small-scale structures which vary from mappable flexures to small drag folds. Intense compression is evidenced by thrusting and interwedging of strata along joints and bedding planes, fracturing, and brecciation.

TERTIARY DEFORMATION

TETON RANGE AND JACKSON HOLE

Although St. John (1879, p. 412) described the Teton Range as "a great block tilted along its eastern border" and thereby outlined its essential structure, the full significance of the great Tertiary fault along its eastern margin was first appreciated by Blackwelder (1911, p. 463–464; 1915, p. 113–114, p. 214–215) whose interpretation was based largely on physiographic evidence.

Along the Teton fault, pre-Cambrian gneisses and schists rise 7000 feet above late Cretaceous and early Tertiary sediments underlying the floor of Jackson Hole (Pl. 6, fig. 2). The east front of the range is regarded as a composite fault scarp maturely dissected by streams and subsequently modified by glacial erosion. The fault trends

[3] The probable existence of such a fault was called to the attention of the senior author by W. W. Rubey in 1936, and on the geological map of the United States (United States Geological Survey, 1933) a fault is shown by dashed lines.

N. 10° E., transecting Laramide trends, and its dip, judging by facets along the range front and the dip of branch faults, is well over 45° E. Although the Teton Range may be regarded as a single fault block, the internal structure has been complicated by branch faults and by a series of independent faults in the northern part of the range (Edmund, 1941). Of special significance is a large fault directly west of the central group of high peaks which causes them to rise as a horst above the projected backslope of the range. Late basic breccias (lower or middle Miocene) and plateau rhyolites (early Pleistocene (?)) of the Yellowstone volcanic series have been involved in the faulting, and small scarplets cutting glacial deposits along the front of the range (Fryxell, 1938, p. 1881) evidence recent movements along the fault.

The buttes rising from the floor of Jackson Hole are fault-line scarps and structurally are miniatures of the Teton Range (Pl. 6, fig. 1). The Gros Ventre buttes (Pl. 2) are especially close counterparts in trend and asymmetry. In the north part of the town of Jackson, the fault plane along the east butte has been uncovered revealing a dip of 48° S.E. Farther north in the valley, Blacktail Butte (Pl. 2) and Signal Mountain (Grand Teton quadrangle) represent fault blocks with less regular outlines.

HOBACK AND GROS VENTRE RANGE

South of Jackson, the Hoback Range is bordered on the west by a high-angle fault which, to the north, forms a scarp facing Jackson Hole (Pl. 3, fig. 1) and, farther south, separates the range from a foothills area largely underlain by Camp Davis conglomerate. This fault was first noted by Blackwelder (1911, Fig. 53, p. 465) and was named the Hoback fault by Nelson and Church (1943, p. 163). In the vicinity of Game and Horse creeks (Pl. 2) there is clear stratigraphic and structural evidence of faulting; farther south, the fault is indicated by physiographic criteria and the attitude of the Camp Davis beds which dip 18° E. toward the range. The fault has been traced south of Hoback River by Eardley (1944) for about 20 miles.

Movement appears to have occurred along the fault both during and after deposition of the Camp Davis conglomerate. The earlier movements are evidenced by overlap of the fault trace by Camp Davis conglomerate especially south of Hoback River and by the unusual thickness (about 5000 feet) and fanglomerate character of the deposit. Later movements are indicated by steep dips adjacent to the main fault north of Hoback River and by folding and faulting of the conglomerate. The earlier movements occurred before the early Pleistocene Black Rock erosion surface (Blackwelder, 1915, p. 310) was formed along the front of the range between Hoback River and Horse Creek.

High-angle faults of variable trend are present throughout the northwestern part of the Hoback Range and locally are closely spaced to form a mosaic (Pl. 1). All of them transect Laramide structures and in at least two instances there has been downfaulting of major thrust planes. Not all can be shown to be Tertiary but relations to the Hoback fault and truncation of Laramide trends strongly indicate this age.

Along the south flank of the Gros Ventre Range and bordering the Skyline Trail fault for almost 10 miles is a down-faulted area of Pass Peak (?) conglomerate which in places dips over 50° N. toward the mountain front (Pl. 4, fig. 1). Immediately

west of Granite Creek, the Pass Peak (?) is faulted along the Skyline Trail fault and shows downdrag (Blackwelder, 1915, p. 113, Fig. 10, p. 115). Farther east, Tertiary sediments have been stripped away from the mountain front, but it is probable that renewed movements occurred along all of the Gros Ventre fault blocks as an accompaniment to Tertiary diastrophism.

EPEIROGENIC MOVEMENTS

Regional uplift and warping that accompanied Tertiary faulting is evidenced by high-level remnants of Camp Davis conglomerate in the Hoback and Snake River range (Pl. 2) and by three erosion surfaces antedating the earliest stage of glaciation in the region. The anomalous courses of the Snake and Hoback rivers across structure may be explained by superposition of these streams from a cover of Tertiary sediments. The patches of Camp Davis conglomerate high in the Hoback and Snake River ranges are considered remnants of such a cover.

STRUCTURAL INTERPRETATIONS

FORELAND AND GEOSYNCLINE RELATIONS

As the result of deposition during the Paleozoic and Mesozoic eras, there developed in southeastern Idaho and adjoining areas a great geosynclinal lens of sediments which reaches a thickness of over 46,000 feet (Mansfield, 1927, p. 48). Eastward, the sediments thin rapidly on a foreland or platform area on which there where only minor depressions that received more materials than adjoining regions, but none of geosynclinal proportions. The great accumulation of sediments in southeastern Idaho resulted from local downwarping and from an overlapping of the sites of the ancient Cordilleran (Paleozoic) and Rocky Mountain (Mesozoic) geosynclines. The nearness of the Nevadan ranges to the west was responsible for deposition of a great deal of detrital material throughout most of Cretaceous time. Along the northeastern margin of the geosyncline, the change to foreland facies is remarkably sharp and rapid and within a distance of less than 100 miles the section thickens from less than 10,000 feet to more than 30,000 feet. Within the area, the pre-Colorado (Aspen) sedimentary rocks thicken from about 6200 feet in the eastern Gros Ventre Range to about 11,850 feet in the western Snake River Range (Fig. 2). Thus the section almost doubles in thickness within about 50 miles. The area holds a critical structural position within this zone and changes in facies are believed to be reflected in distinctive structural types and in their localization (Figs. 3, 4). These relations have been previously noted (Horberg, 1938, p. 53–55; Chamberlin, 1940, p. 674–678) and the present study affirms earlier conclusions.

FORELAND DEFORMATION

Within the platform area, where a relatively thin covering of sediments rests upon the crystalline complex, the stresses responsible for deformation acted largely within the older rocks. The resulting structure types carry the impress of their superior resistance and the present trends probably reflect ancient structure lines in the base-

ment rocks. The deformation was deep-seated and competent, the amount of vertical uplift large.

TYPES OF STRUCTURE AND THEIR ORIGIN: The structural types found along the Gros Ventre-Teton Laramide axis are similar to those noted by Blackstone (1940, p. 603) in the Pryor Mountains of Montana, and may form a similar sequential series due primarily to lateral compression: an early stage represented by simple, asymmetrical anticlines; a second stage by asymmetrical anticlines which have broken along high-angle reverse faults; and a final stage, with culmination of stresses, by great fault-blocks and low-angle thrust faults.

Unfaulted anticlines within the area are typified by the Bacon Ridge, Tosi Creek, Crystal Creek, and Taylor Mountain anticlines and the initial Gros Ventre arch, prior to modification by faulting, may have had the same general character but on a much larger scale. Folds broken along high-angle faults are represented by the Flat Creek, Nowlin Creek, Crystal Creek, and Rock Creek faulted anticlines. In the two latter structures, unfaulted anticlines pass into faulted anticlines along the strike. The climax of deformation is represented by the three fault blocks in the Gros Ventre Range, along which there was release from compressive stresses in an upward direction, and by the Cache Creek thrust in which release was in a more horizontal direction. In line with this concept of origin by compressive stresses, the fault blocks in the Gros Ventre Range were described by Nelson and Church (1943, p. 151) as "trapdoor" structures, which they defined as follows:

> "A descriptive term sometimes applied to a block-like type of foreland structure, the essential feature of which is a sharply asymmetrical flexure usually broken on its steep flank by a high-angle fault. The flexure or fault or both generally outline two adjacent sides of the block, and displacement is commonly greatest at the corner. The fault surface curves under the block, and in more advanced stages actually becomes a thrust fault, indicating its ramplike character. Trapdoors are thus interpreted as resulting largely from horizontal stresses transmitted through the more competent crystalline complex below the sedimentary cover to pre-existing zones of weakness, where they break up toward or through to the surface to produce a fault having a 'sled-runner'-like profile."

Although the fault blocks do not harmonize with regional asymmetry so closely as the Cache Creek overthrust, it is of interest to note that in the Pryor uplifts where regional asymmetry is to the northeast (Blackstone, 1940, p. 597), the point of maximum uplift is at the northeast corner of each tilted block. With asymmetry toward the southwest in the Gros Ventre Range; the fault blocks have been uptilted at their southwest corners.

The concept that progressively intensified stages of deformation are represented by the Teton-Gros Ventre structures is supported by: (1) similar trends; (2) the localization of major faulted structures along the front of the uplift in areas of maximum displacement and unfaulted anticlines on the backslope where uplift was less; and (3) the fact that several of the unfaulted anticlines pass into faulted anticlines as displacement increases, i.e., the Rock Creek, Crystal Creek, Nowlin Creek, and Cache Creek anticlines.

The compressional origin of the asymmetrical anticlines and the Cache Creek thrust appears well substantiated, but whether the fault blocks are due to uplift by similar stresses or to later down-faulting along the crest of the primary arch is less

certain. Both normal and reverse faults are recognized in folded areas and both types have been postulated in regions where the critical relations are uncertain. In the Gros Ventre Range, the essentially vertical or steep southwestward dip of the fault plain toward the downthrow block suggests normal faulting due to later relaxational movements along the arch. Reverse faulting, however, is strongly indicated by the fact that the faults bounding the blocks in two places pass into unfaulted asymmetrical anticlines (Rock Creek and Crystal Creek anticlines) and by the location of the fault blocks along the same structural trend at the front of the range as the Cache Creek anticline and thrust fault. The Cache Creek thrust appears to end abruptly against the Skyline Trail fault block and there is no evidence that it is present in the upfaulted block, or in front of the block, or that it passes laterally into the high-angle fault bounding the front of the range. The relations hence indicate that the two structures are essentially contemporaneous or the thrust fault is younger. Although the best exposures indicate that the faults bounding the fault blocks are essentially vertical or dip steeply toward the downthrow as normal faults, reverse faulting is indicated by overturning of Mesozoic formations in front of the Skyline Trail fault on the ridge west of Granite Creek (Pl. 2). This suggests that the main faults may pass into high-angle reverse faults with depth and that observed dips toward the downthrow may be along later subsidiary normal faults.

Possible Control by Pre-Cambrian Basement Structures: The influence of basement structure on Laramide trends has been considered by a number of workers in the Middle Rockies (Chamberlin, 1919; 1940, p. 702–704; Thom, 1923, p. 1–13; Cloos and Cloos, 1934, p. 56; Wilson, 1938, p. 868–881; Fanshawe, 1939, p. 1487–1489; Lammers, 1939, p. 1918; Blackstone, 1940, p. 606). The available data on major structure trends in the exposed pre-Cambrian rocks of the Gros Ventre, Teton, and Wind River ranges are given in Table 2 and compared with Laramide trends. The pre-Cambrian trends in the Teton (Horberg and Fryxell, 1942, p. 388, Fig. 1) and Wind River (Richmond, 1945; Baker, 1946, p. 584–586) ranges are known to persist over extensive areas; those in the Gros Ventre Range are largely unknown and the trends reported (St. John, 1879, p. 449–450) apply only to a local area. The data show (1) trend of N. 70° to 90° W. in all three ranges, which coincides closely with the main line of faulting along the southwest front of the Gros Ventre-Teton axis of uplift, and (2) trend of N. 10° to 15° W. in the Wind River and Teton Ranges, which is in accord with many of the faults and folds in the Gros Ventre Range which lie transverse to the main axis of deformation. The data fail to reveal strict parallelism and there are exceptions, but a general coincidence is readily apparent.

The influence of lines of weakness in the basement rocks is also indicated indirectly by the structural pattern and the great vertical uplift. The remarkable parallelism of all three fault blocks extending even to the strike of branch faults is hardly coincidental, and it is unlikely, since deformation clearly extended deep into the crystalline complex, that later movements would be uninfluenced by pre-existing lines of weakness.

GEOSYNCLINAL DEFORMATION

The structures within the geosyncline are typical of areas where a thick lens of relatively weak sediments has been moderately deformed. Within the United States,

the Appalachian and Ouachita structures are most closely analogous. Most intense deformation occurred where the sediments were thickest and the tectonic trends closely parallel the isopach lines (Figs. 3, 4). The amount of horizontal compression was large and the vertical uplift small. Local structures were probably controlled mainly by initial dips and facies changes within the geosyncline, rather than by pre-Laramide structures; and regional trends were determined largely by the position of geosyncline and foreland and the direction of stresses.

In the Hoback and Snake River ranges, the structural trends are in line with the orientation of the geosynclinal trough except in their northern portions where the combined influence of stratigraphic relations suggested by the change in the direction of isopach lines (Fig. 3) and a possible upraised foreland buttress caused a pronounced northwestward deflection.

Maximum uplift within the ranges occurred along the major thrust faults and the oldest Paleozoic rocks generally form the front of thrust sheets. In the areas between the major thrusts there was much less vertical displacement and the folded structures involve incompetent Mesozoic formations.

The position of the thrust planes in many places coincides with shaley beds in the Paleozoic sequence, especially the Gros Ventre shale (Cambrian) and the shales in the upper part of the Darby formation (Devonian), and the Amsden shale (Pennsylvanian). This relation is more apparent in the Snake River Range than in the Hoback Range where the fault planes commonly transect younger Mesozoic beds and there appears to have been important folding before thrusting.

The total amount of horizontal compression in the geosynclinal area, as evidenced by close folding and thrusting, was much greater than that in the adjoining foreland and it is probable that the rapid changes in facies within the area have been emphasized by crustal shortening amounting to several miles.

Folding followed by thrust faulting appears to have been the general order of deformation. This is indicated by the localization of thrust faults along major anticlinal axes in the Snake River Range and by the transection of older folds by thrust planes in the Hoback Range. The order in which the thrust faults were formed is uncertain from the evidence now available within the area. However, in the Hoback Range just south of the area, the easternmost thrust sheets are overlapped by the Pass Peak conglomerate, whereas along one of the thrust sheets to the west, which is intermediate between the Darby and Bear Creek thrust faults (Pl. 1), Pass Peak beds are involved in the faulting (Eardley, 1944).

THE FORELAND BUTTRESS

The view that the foreland structures of the Gros Ventre and Teton ranges acted as a buttress against which the superficial structures in the weaker sediments of the geosyncline impinged is supported by three lines of evidence:

1) The abrupt change in the trend of geosynclinal structures where they contact and become parallel to those of the foreland in the northern part of the Snake River and Hoback ranges.

2) The crowding and convergence of fold axes, accompanied by intensified thrust faulting, along the northern margin of the geosynclinal belt.

3) The superposition of the Jackson thrust upon the southwest limb of the Taylor

Mountain anticline west of Teton Pass, where progressively younger beds appear from below the thrusts sheet with marked angular divergence (Pl. 2).

Somewhat similar buttress relations have been suggested at two other points within the Middle Rockies where foreland and geosynclinal structures meet: at the northwest corner of the Beartooth Range (Lammers, 1937, p. 293) and at the west end of the Uinta Range (Butler, Loughlin, and Heikes, 1920, p. 251–254). Outside the Middle Rockies, other examples are: the Adirondack buttress and Appalachian Valley structures in northwestern Vermont (Bucher, 1933, p. 241); the Arbuckle buttress and Ouachita trends in southeastern Oklahoma (Miser, 1929, p. 24); the crowding of the northeastern Jura folds against the Black Forest massif in Switzerland (Heim, 1919, Pl. 20, p. 548 and fig. 103, p. 615).

Whether the time relations for geosynclinal and foreland deformation established for the local area can be applied to the Middle Rockies as a whole is open to question. Theoretical considerations suggest that a reversal of the sequence would be more probable and that initial deformation began in the weak axial portion of the geosyncline rather than in the foreland. This view is not thought to violate the local sequence, since the thrusting in the Snake River and Hoback ranges probably represents the culmination of compressive forces within the geosyncline. Although yielding actually began in the deepest portion of the trough, the final phases of thrusting and marginal folding might well have taken place after the uplift of early foreland structures.

RELATION OF GROS VENTRE STRUCTURES TO THE WIND RIVER RANGE

Near the eastern edge of the area, the major axis of uplift forming the Gros Ventre Ranges plunges east and terminates about 3 miles east of Gros Ventre River against a syncline which fronts the marginal thrust faults of the Wind River Range (Fig. 4). Where the structure crosses Gros Ventre River, the Phosphoria formation is exposed along the axis of the fold (Pl. 2). North and south of this area the two ranges diverge structurally and topographically. Although the major Gros Ventre arch meets the Wind River Range at a high angle, the subordinate folds in the Gros Ventre Range (Bacon Ridge and Tosi Creek anticlines) are essentially parallel to marginal structures in the Wind River Range.

A possible additional structural relationship between the two ranges is suggested by the presence of several small outliers of Paleozoic rocks (Cambrian to Mississippian) which lie 1–2 miles southeast of the southeast corner of the area (Pl. 2) in the northern part of the Green River basin (Fig. 4). The outliers form small buttes which are isolated from both ranges and appear to be surrounded by Cretaceous and Tertiary strata, although the intervening areas are largely covered with glacial drift. They were interpreted as klippen by Richmond (1945) and Baker (1946, p. 584) and considered remnants of an overthrust sheet which once extended westward at least 5 miles from the present front of the Wind River Range. Structural features in the eastern Gros Ventre Range support this interpretation and the thrust sheet could not have had its roots in the Gros Ventre Range because: (1) no thrust fault was recognized in the eastern part of the Gros Ventre Range; the structure closest to the klippen on the north is the south limb of a broad arch flanked by upper Cretaceous forma-

tions; (2) deformation in the Gros Ventre Range decreases rather than increases in intensity from west to east in the direction of the klippen; and (3) the structural trends indicate dominant Laramide stresses from the northeast rather than from the northwest as would be implied if the klippen were related to Gros Ventre structure.

TABLE 2.—*Pre-Cambrian and Laramide structure trends*

Locality	Pre-Cambrian	Laramide	Reference (Pre-Cambrian)
Gros Ventre Range	Cleavage.....E.–W., N.45°W., E.N.E.	Major arch.....N.65°W. Major faults.....N.60°W.–N.70°W., N.30°W. Secondary folds....N.10°W.–N.30°W.	St. John (1879, p. 449–450).
Teton Range	Major foliation.....N.10°W. Joints and dikes....E.–W.	Folds.....N.60°W.–N.30°W.	Horberg and Fryxell (1942, p. 388, Fig. 1).
Northwest Wind River Range	Major fracture zones N.35°W., N.–S. Secondary fractures and dikes.....N.70°W., E.–W.	Major arch.....N.35°W. Major faults.....N.35°W.	Richmond (1945); Baker (1946, p. 584–586).

TERTIARY MOVEMENTS

The trends of Tertiary faults (Pl. 1) differ sharply from the strike of earlier structures and show none of the controls exerted by foreland and geosyncline relations. The faults transect Laramide structures and are the only major trends in the region which strike east of north. Structures in the pre-Cambrian complex at least locally influenced their strike. This is best indicated by the general parallelism of the east scarp of the Teton Range to the strike of the crystalline rocks forming its cores.

The Teton Range fault block and the fault blocks in Jackson Hole are of Basin-Range type and exhibit unusually well the four elements considered most characteristic of the type: (1) earlier structures preserved in the interior of the ranges (Fig. 4), (2) a surface of subareal erosion truncating these structures, (3) a lava cap preserving the surface of erosion, and (4) tilted fault-block mountains (Davis, 1930, p. 293–313). To the south in Utah and southeastern Idaho, Basin-Range faults occur in conjunction with Laramide structures, and less than 100 miles to the west, similar structures extend north of the Snake River plains in Idaho (Anderson, 1934, p. 17–28) and into Montana. The position, trend, and type of Tertiary faults in western Wyoming suggest that the areamay be a marginal section of the Basin-Range structural province.

Epeirogenic movements affecting the region during the late Tertiary and throughout the Quaternary appear to have been in the nature of differential uplifts of ranges

and basins, and unlike the Tertiary faults, generally followed axes of Laramide uplifts. Except for the Teton Range, there is a general accordance of present topography with Laramide structure. This relation seems to be characteristic of the foreland ranges of the Middle Rockies, whereas in the southern Northern Rockies the present ranges are seldom in harmony with tectonic trends.

DIASTROPHIC HISTORY

INTRODUCTORY STATEMENT

Nine diastrophic episodes are indicated by structural relations and sediments within the area (Table 3) and, although record is probably incomplete, they are believed to be sufficiently distinct to outline major events.

NEVADIAN DISTURBANCE

The Nevadan disturbance, which affected central Idaho and other areas to the west, is recorded in the sandstones and conglomerates of the Gannett formation and by clastics and volcanic tuffs in the lower Cretaceous formations. A notable feature is the appearance of abundant heavy minerals in the sandstones at the base of the Gannett and their continued occurrence in lower Cretaceous formations.

LARAMIDE STAGES OF DEFORMATION

The Laramide structures belong to the same general period of mountain building, but, as elsewhere in the Rocky Mountains, the time interval was extended and several orogenic stages were involved. Further information is needed to date these events in central western Wyoming, and until detailed studies of late Cretaceous and Tertiary formations in the basin areas are made, many problems will remain unsolved. Three and possibly four stages extending from late Cretaceous through the Eocene are recognized (Table 3):

(1) Main folding and faulting in the Gros Ventre and Teton ranges and possible early folding in the Hoback and Snake River ranges. The early foreland structures were probably asymmetrical anticlines which later broke along high-angle faults and culminated in thrust faulting along the Cache Creek anticline. These structures acted as a buttress against which the early folds and later the thrust sheets of the geosyncline impinged. The transection of folds by thrust faults, especially in the Hoback Range, indicates early folding in the geosyncline. Deformation occurred in post-Frontier (Late Cretaceous)—pre-Hoback (upper Paleocene) time.

(2) Main folding accompanied by some thrust faulting in the Snake River and Hoback ranges. This episode is distinguished by the deflection of geosynclinal trends around the south margin of the foreland buttress and may have followed closely upon stage (1). It preceded deposition of the Hoback formation along the northeast front of the Hoback Range.

(3) Main thrust faulting along the east front of the Hoback Range. South of Hoback River, the Cliff Creek thrust can be traced southward to a point near the South Fork of Hoback River where the frontal thrust sheet involves the Hoback

formation but is overlapped by the Pass Peak (Middle Eocene) conglomerate (Eardley, 1944).

(4) Later thrust faulting in the Hoback Range. The final stage of thrusting occurred after deposition of the Pass Peak conglomerate (Middle Eocene) and is

TABLE 3.—*Diastrophic episodes in western Wyoming and southeastern Idaho*

	Epoch	Gros Ventre, Teton and Hoback ranges	Southern Absaroka range and Gros Ventre basin (Love, 1939, 1937)	Southeastern Idaho (Mansfield, 1927)
Basin-Range faulting	Recent	Normal faulting (5)		
	Pleistocene	Uplift Normal faulting (4)		
	Pliocene	Uplift (3) *Normal faulting (2)	Uplift, normal faulting Local folding and faulting	Uplift
	Miocene	Normal faulting (1)		Normal faulting
	Oligocene		Tilting Local folding and tilting	
Laramide Revolution	Eocene	Thrusting (4)	Local folding Thrusting Gentle folding and thrusting *Folding and faulting	
	Paleocene	*Folding and thrusting (3) *Folding and thrusting (1), (2)	Gentle doming *Folding and faulting	*Thrusting
	Montana			

* Major deformation.

evidenced by movements along the Little Granite Creek thrust in the northern part of the range and possibly by further movements along the front of the Skyline Trail fault block. Farther south in the Hoback Range, a thrust sheet with its roots in the center of the range comes to the front of the range and overrides Pass Peak conglomerate (Eardley, 1944). The thrust faults in the Snake River Range, since they lie behind this fault, may belong to the same or a slightly later stage of deformation.

TERTIARY FAULTING AND EPEIROGENIC MOVEMENTS

Basin-Range faulting appears to have occurred intermittently throughout the latter half of the Cenozoic epoch with the major movements in the Miocene and Pliocene. Later epeirogenic movements recorded by erosion surfaces probably took place in the late Pliocene and early Pleistocene. The following stages are indicated:

(1) Initial movements along the Hoback fault which gave rise to deposition of the

Camp Davis conglomerate (Upper Miocene-lower Pliocene) in the adjoining trough. Movements doubtless continued during deposition, but south of Hoback River the upper conglomerates overlap the fault trace. The branch faults in the northern part of the Hoback Range were probably initiated at the same time. The scarcity of crystalline rocks in the Camp Davis conglomerate suggests that major uplift of the Teton fault block had not yet occurred.

(2) Main Teton faulting and renewed movement along the Hoback fault and related faults. At this time the Camp Davis conglomerate north of Hoback River was faulted along the Hobeck fault and tilted east.

(3) Epeirogenic movements gave rise to the following erosion surfaces, from oldest to youngest: Union Pass subsummit surface, Black Rock mature valley stage, Squaw terraces, and Circle terraces (Blackwelder, 1915, p. 310–319; Fryxell, 1930, p. 16–25; Horberg, 1938, p. 60–75). These movements occurred after the main Teton faulting (stage 2) but were in part contemporaneous with later movements along the fault. At the north end of the Teton Range, the Black Rock surface appears to be covered by Yellowstone Plateau rhyolites (Fryxell, Horberg, and Edmund, 1941, p. 1903). The lower surfaces were developed during the glacial epoch and can be related to stages of glaciation (Table 1).

(4) Later movements along the Teton fault. A series of minor movements is indicated by faulting of the plateau rhyolites (early Pleistocene (?)) at the north end of the Teton Range.

(5) Recent movements along the Teton fault are evidenced by scarplets cutting late Wisconsin moraines just north of the area near Jenny Lake (Grand Teton quadrangel) (Fryxell, 1938, p. 1881), and by recent earthquakes in the region (Blackwelder, 1926, p. 196; Fryxell, 1933, p. 167–168; Gale, 1940, p. 85).

SUMMARY

In central western Wyoming foreland and geosynclinal structures of Laramide age are in close proximity and of distinctive types and trends. The foreland structures trend northwest and are represented by the Gros Ventre Range and by the continuation of its axes of folding into the Teton Range. The structural types of the foreland are grouped into a genetic and chronologic sequence which begins with a simple asymmetric anticline, continues by the steep limb breaking along a high-angle reverse fault, and culminates with low-angle overthrusting or with uplift along great fault blocks. The asymmetry of the structures is to the southwest in all cases and overthrusting has been in that direction. Certain elements in the tectonic pattern were probably influenced by structural lines of weakness in the pre-Cambrian crystalline rocks.

The geosynclinal structures are represented by close folds of Appalachian type which occur with major low-angle overthrust faults in the Hoback and Snake River ranges. The results are represented by the St. John, Absaroka, Darby, and Jackson thrusts, and by several others which may not be of regional significance. All dip at low angles to the southwest. The prevailing trend of the geosynclinal structures is north except at points of contact with the Teton and Gros Ventre ranges where they are deflected northwestward into parallelism with the structures of the foreland.

The area is located along the northeastern edge of a thick geosynclinal wedge of sediments most fully developed in southeastern Idaho. The sediments thin rapidly to the northeast so that the Gros Ventre and Teton ranges are within a platform area. The structures of the foreland resulted from deep-seated stresses in the basement rocks which produced great vertical uplifts in the centers of which the crystallines are now exposed. The deformation observed within the geosyncline was surficial and emphasized horizontal compression. The foreland structures developed first and acted as a buttress against which the geosyncline was crowded. Initial phases of orogeny probably began in the late Cretaceous and continued until late Eocene time.

Laramide structures are transected by high-angle faults of Basin-Range type which trend in a general northerly direction. Faults of this type are responsible for the impressive east scarp of the Teton Range, small fault blocks rising above the floor of Jackson Hole, and for the west boundary fault of the Hoback Range. Most of the faulting occurred during the late Tertiary, but movements have continued to the present.

Epeirogenic movements during the late Tertiary and Pleistocene repeatedly accelerated erosion and are responsible for the development of present landforms.

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